Universitat Autònoma de Barcelona

Exploring Word-Medial Regressive Voicing Assimilation in Catalan L2 Learners of English

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Abstract

It is widely acknowledged that phonological processes of the L1 are transferred to the L2. In Catalan we find two processes, Regressive Voicing Assimilation (RVA) and Final Obstruent Devoicing (FOD), which are generally transferred to English. The aim of this paper is to examine whether or not these L1 processes are still present in the English L2 production of advanced learners. Specifically, I study the production of alveolar fricatives /z/ and /s/ followed by a voiceless consonant, a voiced consonant, a nasal, and a vowel –contexts expected to trigger RVA–, and in final position –expected to trigger FOD. The participants are nine Catalan native speakers with an advanced level of English and two native English speakers who served as the control group. They were recorded whilst reading a list containing sentences with the aforementioned sound sequences. Preceding vowel duration, voicing during the fricative, and fricative duration, which are the three main cues for fricative voicing in English, were analysed. None of the L2 speakers of English uses the three cues across all contexts studied in this paper, and few seem to master more than one cue. RVA and FOD seem to go hand in hand in L2 acquisition.

Key words: SLA, regressive voicing assimilation, final obstruent devoicing.

1. Introduction

1.1 Regressive Voicing Assimilation and Final Obstruent Devoicing

It is widely agreed that L2 production is strongly influenced by the speaker's L1 phonetic categories and processes. The present study attempts to examine the transfer of Catalan (L1) phonological processes concerning voicing in obstruents to English (L2). Catalan is among the languages whose obstruents assimilate the voicing specification of the following segment, a process known as Regressive Voicing Assimilation (RVA). For instance, in a sequence such as *els altres* ('the others') /əls ‘altrəs/, the first instance of /s/ assimilates the voicing of the following segment, becoming [əlz ‘altrəs]. In like manner, a sequence such as *els tomàquets*(‘the tomatoes /əlstu'makəts/ becomes [əlstu'makəts]. In Catalan, RVA affects stops, fricatives, and affricates in medial, e.g. *estirar* [st], *esdevenir* [zð], and word final position, followed by a consonant [dəs’pres ‘tornu] (*després torno*), [dəs’prez ‘ðeʎ] (*després d’ell*), and it does not apply when the final consonant is followed by a pause. RVA, however, is not a process present in English: *twice a day* /’twaɪsə ‘deɪ/ or *twice daily*/’twaɪs‘deɪlɪ/ can only be pronounced with a voiceless fricative (/s/). A number of studies (Cebrian, 2000; Nobau, 2017, among others) have shown that native Catalan speakers transfer this process from their L1 to English (L2) obstruents.

Another process to take into consideration is Final Obstruent Devoicing (FOD), where voiced obstruents are realised as voiceless when produced in final position. For instance, *solitude* (‘loneliness’) is produced as [t]. FOD may be accounted for by aerodynamic reasons. In order to produce voicing, the subglottal pressure has to be higher than the pressure in the oral cavity. During a voiced obstruent, the air flowing from the lungs rises the supraglottal pressure, due to the partial or complete articulatory closure for the obstruent, and voicing ceases (Cuartero, 2001: 6). This results in devoicing of final obstruents which has become the norm in a number of languages, such as Catalan. English final obstruents may show vocal fold vibration in final obstruents because, “English speakers learn to enlarge the supraglottal cavity to sustain voicing during the closure”

(Flege, 1997 cited in Cebrian, 2000: 3). Native speakers of Catalan transfer Final Obstruent Devoicing into their L2.

FOD, as we have seen with RVA, is an L1 routine that appears to become fossilised and therefore extremely is difficult to modify in order to produce native-like L2 sounds. In English, vocal fold vibration during the obstruent constriction and preceding vowel duration serve as the main cues for voicing in syllable and word final obstruents. In Catalan, only the former plays a role in cueing voicing. Studies have concluded that a vowel longer than 200 m indicates a following voiced obstruent whereas a vowel shorter than 200 ms indicates a following voiceless obstruent (Raphael, 1971). The voiceless to voiced ratio of preceding vowel duration in English is approximately 1:3, that is, vowels tend to be 30% longer before a voiced obstruent regardless of whether the obstruent is devoiced or not. This study aims to analyse whether native speakers of Catalan are aware of such distinctions and whether they show differences in obstruent voicing and vowel duration or, conversely, fail to produce the English cues for voicing.

1.2 Voicing patterns in other languages

Catalan is not the only language in which RVA and FOD take place. In Russian, both regressive voicing assimilation (1*a*, 1*b*) and final obstruent devoicing (1*c*) take place (Burton, 1996; Petrova *et al*, 2006). As in Catalan, FOD occurs in word-final position if there is no following segment (Petrova *et al*, 2006), and voicing assimilation occurs across word and morpheme boundaries.

a. le[d]ok ‘ice’ nom. sg.	le[tk]a gen. sg.	RVA
b. pro[s’]it’ ‘to beg’	pro[z’b]a ‘request’	RVA
c. vra[k] ‘enemy’ (nom. sg.)	vra[g]a (gen. sg.)	FOD

In Hungarian (Markó*et al.*, 2010), regressive voicing assimilation occurs in all instances except if there is a pause that intervenes. Within word-boundary, suffixed forms undergo RVA in both directions: voiceless obstruents become voiced when followed by a voiced segment (1a), and voiced obstruents become voiceless when followed by a voiceless consonant (2b).

(2) a. zsák [ʒa:k] 'sack' + ban [bɔn] 'inessive' →zsákban [ʒa:gbɔn] 'in (a) sack'

b. nagy [nɔé] 'big' + kutya [kucɔ] 'dog' →nagykutya [nɔckucɔ] 'big dog'

(Markó*et al.*, 2010: 212)

Loanwords from other languages also adopt this process, e.g.,*futball*[fudbɔl] ('football'). Another relevant language exhibiting this process is Korean, which has a three-way distinction in obstruents: voiceless unaspirated (plain), voiceless glottalised (tense) and voiceless aspirated obstruents. FOD, therefore, does not take place in Korean. Although apparently we do not find voiced obstruents in this language, plain obstruents become voiced between voiced segments (Major & Faudree, 1996). For instance, /mɛn#pal/ ('barefoot') becomes [mɛnbal]. It has been found that Korean native speakers transfer this voicing assimilation process to their L2. FOD does not take place in Korean.

Table 1. Voicing patterns in other languages.

Language	Process	Example	Gloss
Catalan	RVA	*Els altres*[əlz 'altrəs]	'the others'
	FOD	*magnitud* [magnɪ'tut]	'magnitude'
Russian	RVA	le[tk]a	'ice'
	FOD	vra[g]a	'enemy'
Hungarian	RVA	[ʒa:gbɔn]	'in (a) sack'
	FOD	x	
Korean	RVA	[mɛnbal]	'barefoot'
	FOD	x	

2. Literature Review

This paper takes as starting point Carla Nobau's *Regressive Voicing Assimilation: Catalan Native Speakers' Performance in Advanced L2 English* (2017), where she analysed voicing assimilation in obstruents across words. She states that, although there is variability across participants, "an advanced level of English does not translate into a good production of final fricative voicing contrasts" (Nobau, 2017: 25). Regarding RVA, the results of the study reflected interspeaker variation, with only one non-native speaker of English showing a native-like pattern. In addition, few speakers seem to master vowel length to indicate obstruent voicing, in sum, advanced learners of English transfer their L1 processes and fail to produce the L2 cues for voicing.

In like manner, Cebrian (2000) studied the transferability of L1 patterns to English and markedness as an important factor causing L2 errors. The experiment tested 4 Catalan native speakers living in Canada on their production of final English obstruents in four different environments. He found that subjects had great difficulty producing such segments, especially voiced obstruents, for two reasons: markedness and the difficulty involved in maintaining vocal fold vibration during the final obstruent (Cebrian, 2000: 3). He mentions that neither speakers' proficiency nor length of residence (LOR) in the English-speaking country played an important role in the results.

Fullana and MacKay (2008) explored the influence that age of onset of learning (AOL) and exposure to the L2 could have on the production of voicing contrast of final obstruents by Catalan and Spanish bilinguals L2 learners of English. They tested 47 participants with different AOL and in exposure to English. The results show that Catalan/Spanish bilinguals "resort to L1 production rules" (Fullana & MacKay, 2008: 119), in this case FOD. Moreover, these participants failed to produce the average voiced to voiceless ratio expected (<1.30) and presented longer voiced than voiceless obstruents.

Much research has been conducted to account for foreign accent in L2 acquisition. The most common hypothesis is the passing of a critical period, which suggests that the necessary mechanisms for a successful L1 acquisition lose their effectivity around age 12 "due to a decrease in brain plasticity" (Flege, 2002: 217). There are several studies, however, that contradict such hypothesis. It has been proved that in some cases, some speakers who began learning their L2 past the critical period have a native-like production, as well as speakers having learned their L2 before the passing of the critical period who have a foreign accent (Flege, 2002).

Flege (1995, 2002) proposed the Speech Learning Model (SLM), which aims to account for the aspects of L1 which hinder the acquisition of L2 sounds. The SLM postulates that "the mechanism and processes used in learning the L1 sound system, including category formation, remain intact over the life span, and can be applied to L2 learning" (Flege, 1995: 239). It posits that the phonic elements of both L1 and L2 exist in a "common phonological space" (Flege, 2002: 224) and, therefore, influence one another. According to this model, if an L2 phonetic category is perceived as a previously established L1 category, the former is said to have been "equated with the L1 speech sound" (Flege, 2002: 224). Therefore, the capacity to form new categories is not lost but learners fail to form new categories for those L2 sounds that are phonetically closer to the L1 sound. For instance, [t^h] is perceived by native speakers of Catalan as [t], since there is only a two-way distinction in Voice Onset Time (VOT) in Catalan –negative and zero VOT–, as opposed to the three realizations found in English –negative, zero, and positive VOT–. The SLM proposes two mechanisms that account for the interaction between L1 and L2 sound systems: category assimilation, through which category formation is blocked, and category dissimilation, through which a new category will be formed for the L2 sound.

Similarly, Best's perceptual assimilation model (PAM) supports the hypothesis that L1 phonetic processes influence the acquisition of L2 sounds. PAM was designed to address theoretical gaps present in SLM. Of the existing non-native speech perception models, only PAM makes predictions "about assimilation and dissimilation differences for diverse types of non-native contrasts" (Best *et al.*, 2001: 4). This model posits that speakers are aware of the articulators and processes involved in the production of native sounds and, therefore, assimilate non-native phones to native phonemes based on their possible similarities. PAM categorises the assimilation of non-native sounds in three possible ways:

> (1) as a Categorized exemplar of some native phoneme, for which its goodness of fit may range from excellent to poor; (2) as an Uncategorized consonant or vowel that falls somewhere in between native phonemes (i.e., is roughly similar to two or more phonemes); or (3) as a Nonassimilable nonspeech sound that bears no detectable similarity to any native phonemes.

This paper will base the analysis of the data resulting from the experiment on the hypotheses and predictions postulated by these speech perception models.

The main goal of this study will be to analyse how Regressive Voicing Assimilation occurs within words, as opposed to Nobau's (2017) study which focused on RVA across words. Although the production of Catalan L2 speakers of English has been previously analysed, the focus was on instances where RVA occurred across word-boundary (Cuartero, 2011; Nobau, 2017), with little emphasis on within-word assimilation. A second goal is to examine if RVA is related to FOD, and if the two processes are aligned in Catalan speaker's English production. The research questions are the following: firstly, does Regressive Voicing Assimilation occur within words in Catalan advanced students of English? If it does, does it show the same pattern as in word-final position? And secondly, does FOD go hand in hand with RVA in L2 acquisition, or are they two separate processes? Considering the results on previous studies, the hypotheses of this paper are that (1) Catalan native speakers will transfer their L1 processes, in this case RVA within word boundary and FOD, into their L2 (English), and (2) that the two processes go hand in hand in L2 acquisition.

3. Methodology

3.1 Participants

Eleven subjects (2 males and 9 females) were asked to participate in the study: two English native speakers that served as control and nine native Catalan speakers. They are students of 4th year of English Studies and professors of the English department at Universitat Autònoma de Barcelona. In order to assess the proficiency in English of the experimental group, the *Straightforward Upper Intermediate and Advanced Placement Test* by Macmillan Publishers was administered, which divided the participants into Upper Intermediate and Advanced levels. All native speakers of Catalan have received phonological training in English and have varying degrees of knowledge of phonetics and phonology.

3.2 Material

Subjects were asked to read a list of sentences that contained the target sounds within meaningful sentences. Distractors were placed randomly across the list. The target sounds were both voiced and voiceless alveolar fricatives, /z/ and /s/, followed by a vowel (_V), a nasal (_N), a lateral ($\_C_{[+voice]}$), a voiceless stop ($\_C_{[-voice]}$) and in final position (_##).

In order to test RVA within words, it was necessary to test (near) minimal pairs with medial sC and zC clusters. Since there are not many instances in English of such sequences within words, compound words were used in most cases (see Table 1).

Table 2. Sentences provided in the reading task.

Context	/s/	/z/
$\_C_{[-voice]}$	She was chosen as our class president.	I have discovered a new jazz club.
$\_C_{[+voice]}$	Advanced Syntax is in a different classroom.	His band plays jazz-rock.
_N	I have always got on well with my classmates.	He's always been a great jazz-musician.
_V	20% of the final mark is based on class-attendance.	Some could call him a jazz addict.
_##	I was told of for speaking in class.	Young people are not usually into jazz.

Environments that are expected to trigger foreign RVA (1) and FOD (2) in Catalan speakers are the following.

(1) *a.* Advanced Syntax is in a different classroom.

b. I have always got on well with my classmates

c. 20% of the final mark is based on class attendance

d. We have discovered a new jazz club.

(2) Young people are not usually into jazz.

The tonic pattern of the sentences was kept consistent and was designed to place the target sounds in focus position to avoid any possible influence that intonation could have in their pronunciation. The participants were instructed to read the randomised list three times. The participants were recorded in the speech lab (Servei del Tractament de la Parla) at UAB.

3.3 Data analysis

The recordings were segmented and further analysed with Praat. Preceding vowel duration, voicing during fricative and total fricative duration were measured in this study, which are the main cues for voicing in English; the tokens were measured in terms of milliseconds. Preceding vowel duration was measured from the first peak of periodic energy until the appearance of random noise. Voicing during fricative was measured from the onset of friction alongside vocal fold vibration — periodic energy— to the beginning of random noise —aperiodic energy—. The period from the beginning of the aperiodic energy until the end of high energy was measured —the voiceless period of the fricative— was measured to obtain percentage of voicing during friction as well as the total duration of such obstruents. Both waveform and spectrogram were taken into account in the acoustic analysis of the segments.

Regressive Voicing Assimilation in Catalan does not occur after a pause, hence the decision to discard those tokens in which the participant stopped after the fricative. Also, some participants failed to produce the correct stress pattern in some instances of sequences such as [‘ʤæz ’ædɪkt] (*jazz addict*), pronouncing instead [ˌʤæzʔə’dɪkt]. Given the presence of a glottal stop between the fricative and the following sound, such tokens were also discarded.

4. Results

Given the great amount of both intraspeaker and interspeaker variation in FOD and RVA, the two processes will be analysed separately in terms of the aforementioned cues. The different subsections will be dedicated to the results obtained concerning preceding vowel duration, voicing during friction and fricative duration.

4.1 Final Obstruent Devoicing (FOD)

4.1.1 Preceding Vowel Duration

Preceding vowel duration is one of the most salient cues for obstruent voicing, especially in final position where voiced obstruents are partially devoiced in English. As mentioned before, the voiced to voiceless ratio of preceding vowel duration is approximately 1.30. Taking this into consideration, four different patterns were established among the participants: native speakers (NS), L2 speakers who produced a voiced to voiceless ratio longer than 1.25 (Foreign Speakers= FS1), L2 speakers who produced a ratio in the right direction, i.e., longer vowels before voiced consonants, although the difference is not sufficiently large for English (FS2), and L2 speakers who produced longer vowels when preceding a voiceless fricative (FS3) (see Table 2).

Table 3. Vowel duration ratios before voiced and voiceless fricatives in a FOD context and grouping of participants. ≥1.25 ratios marked in yellow.

Preceding Vowel Duration		
NS	**AM**	1.47
	J	1.29
FS1	**AB**	1.65
	ST	1.25
FS2	**JC**	1.17
	MX	1.16
	CL	1.15
	NR	1.15
	JUD	1.13
	ER	1.09
FS3	**AS**	0.83

The control group composed by native speakers (AM, J) produced the expected voiced to voiceless ratio, despite variation between the two speakers. AM has an average vowel duration of 270.3 ms when preceding a voiced fricative and 183.9 ms when preceding voiceless fricative in a /_## context (voiced-to-voiceless ratio of 1.47). Participant J does not produce such a large difference between those vowels preceding a voiced (269 ms) and a voiceless fricative (209.2 ms). However, with a ratio of 1.29 her values are expected for a native speaker (see Figures 1 and 2).

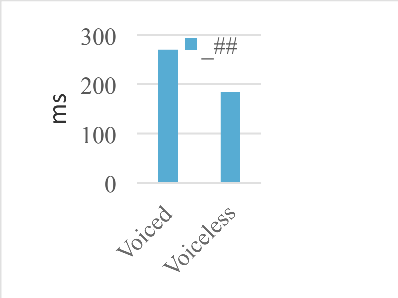

Figure 1. Mean vowel duration for native speaker AM.

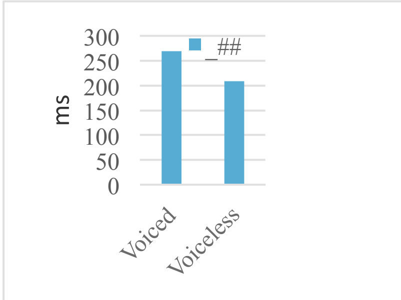

Figure 2. Mean vowel duration for native speaker J.

The FS1 group is composed by those Catalan native speakers who produced vowel duration differences in a native-like manner (AB, ST). Again, there is variation between the two participants that conform the group but both AB and ST produce a voiced-to-voiceless ratio of 1.25 or longer. AB (Figure 3) presents vowels an average of 200.4 ms before /z/ and of 121.1 ms before its voiceless counterpart. ST (Figure 4) has an average vowel duration of 214.3 ms before voiced fricatives and of 171.7 ms before voiceless fricatives. The ratio for both participants is of 1.65, and 1.25 respectively. FS1 constitutes the only group that has acquired vowel length as a cue for obstruent voicing in final position.

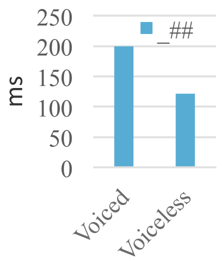

Figure 3. Mean vowel duration for FS1 speaker AB.

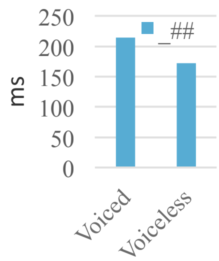

Figure 4. Mean vowel duration for FS1 speaker ST.

The FS2 group, composed by the majority of the native Catalan participants (NR, CL, MX, JC, JUD, ER), includes those speakers who produced longer vowels when preceding a voiced fricative, although they fail to produce a noticeable difference with those vowels preceding a voiceless fricative, i.e., the voiced-to-voiceless ratio of these participants are below 1.17. T-Tests were run for each participant of this group to determine whether the difference in vowel length before /z/ and /s/ was significant. Only one participant, JC —who has a voiced to voiceless ratio of

1.17— produced a statistically significant difference for such instances ($t(5)=3.4$, $p<0.05$). As we can see in Figure 5, the vowels preceding /z/ are on average 216.1 ms long, and 185 ms long when preceding /s/ in the same context. All the other participants have ratios that range from 1.16 (MX) to 1.09 (ER). Such small differences would most likely not be sufficient to cue voiced vs voiceless obstruents in English. The participants in group FS2 seem to be aware of such cue but fail to produce it in a native-like manner.

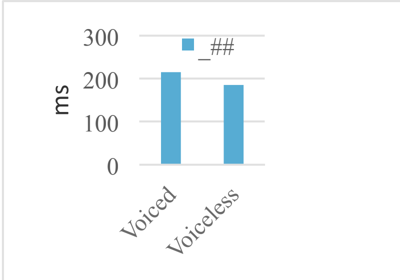

Figure 5. Mean vowel duration for FS2 speaker JC.

FS3 is composed by only one participant, AS, who produced longer vowels when these preceded voiceless fricatives. The voiced to voiceless ratio of this participant is 0.83. The vowels are an average of 150.3 ms before voiced fricatives and 181.6 ms before voiceless fricatives (see Figure 6). This participant has not acquired the desired length distinction and fails to cue voicing in final position by means of the preceding vowel duration

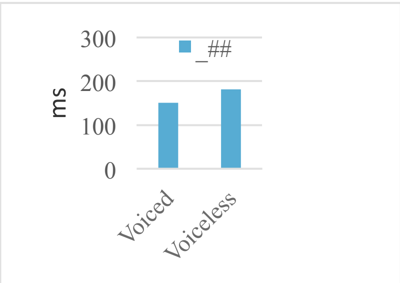

Figure 6. Mean vowel duration for FS3 speaker AS.

4.1.2 Voicing during the Fricative

As stated above, only voiceless obstruents occur in final position in Catalan due to FOD. In English, however, though final obstruents may be devoiced is due to the difficulty of maintaining vocal fold vibration in such context. The distinction between /z/ and /s/ is maintained. Voicing during the fricatives constriction was measured for voiced and voiceless final fricatives. The measurements suggest a three-way division: native speakers (NS), L2 speakers of English who behaved native-like, i.e., presented partial devoicing of final voiced fricatives but maintained a

Table 4. Percentage of voicing during the fricative in a FOD context and grouping of participants.

Voicing during fricative (%)		_## /z/	_## /s/
NS	**AM**	7	2
	J	10	3
FS1	**ER**	23	0
	AB	5	0
	CL	12	5
	JUD	27	0
	ST	37	14
FS2	**NR**	12	11
	MX	6	5
	JC	5	6
	AS	3	3

difference in duration of voicing with voiceless fricatives (FS1), and those L2 speakers who failed to produce such difference and presented FOD (FS2) (see Table 3).

Native speakers present a clearly devoiced final /z/ although it has more voicing than its voiceless counterpart. The rather small difference indicates that voicing during the fricative is not a reliable cue to voicing contrast in comparison to preceding vowel duration. NS AM and J present 7% and 10% of voicing in voiced fricatives, and 2% and 3% of voicing in voiceless fricatives (see Figures 7, 8). The latter may be attributed to voicing continuation: vocal folds do not stop vibrating immediately but take a few milliseconds to do so, hence the presence of a few glottal pulses in final voiceless obstruents.

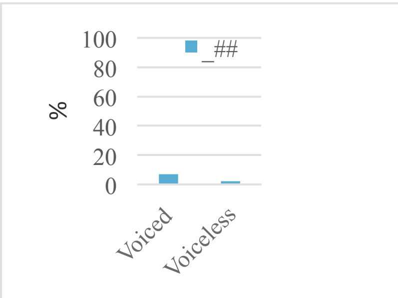

Figure 7. Percentage of voicing in final fricatives for native speaker AM.

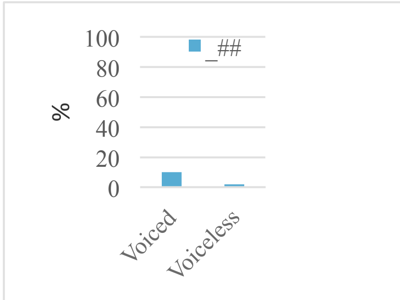

Figure 8. Percentage of voicing in final fricatives for native speaker J.

Participants in the FS1 group present a difference in percentage of voicing in (de)voiced and voiceless fricatives. In Figures 9 and 10 we can see the values for ER and CL who produce, alongside JUD, more voicing in voiced fricatives than native speakers (23%, 12%, 27% respectively), but perform similarly to natives for voiceless fricatives (0%, 5%, 6% respectively). ST shows an overall higher percentage of voicing in voiced and voiceless fricatives (37% and 14% respectively) but presents the correct voicing pattern (see Figure 11).

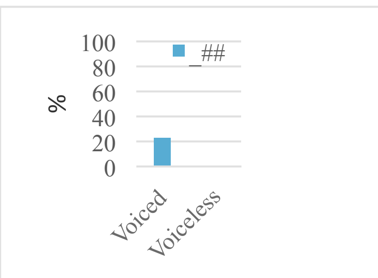

Figure 9. Percentage of voicing in final fricatives for FS1speaker ER.

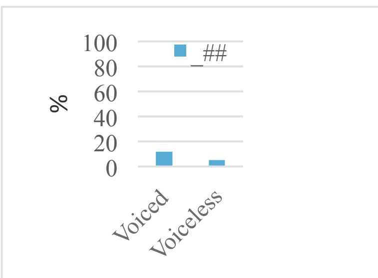

Figure 10. Percentage of voicing in final fricatives for FS1 speaker CL.

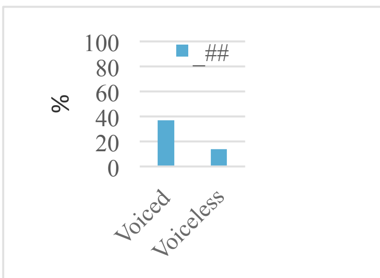

Figure 11. Percentage of voicing in final fricatives for FS1 speaker ST.

FS2 is composed by participants who do not make a difference between voiced and voiceless fricatives in final position. The totality of participants in FS2 presents FOD, although we can observe different patterns. There are speakers who produce only 1% more voicing in voiced than in voiceless fricatives (see Figure 12): NR has 12% of voicing in /z/ and 11% in /s/ and MX has 6% of voicing in /z/ and 5% in /s/. AS presents the same amount of voicing (3%) in both obstruents (Figure 13). JC produces less voicing in voiced fricatives (5%) than in voiceless fricatives (6%) (Figure 14).

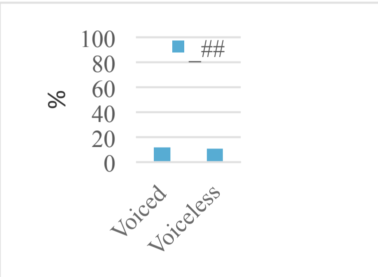

Figure 12. Percentage of voicing in final fricatives for FS1speaker NR.

Figure 13. Percentage of voicing in final fricatives for FS2 speaker AS.

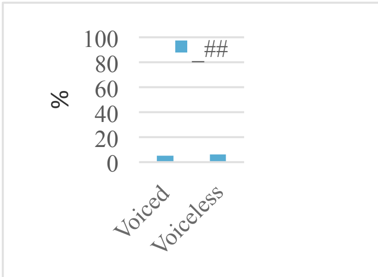

Figure 14. Percentage of voicing in final fricatives for FS2 speaker JC.

4.1.3 Fricative Duration

According to D. H. Klatt (1976) voiceless fricatives tend to be an average of 40ms longer than voiced fricatives. On the basis of this reference value, participants were distributed into three different groups: native speakers (NS), L2 speakers of English who produced longer voiceless than voiced fricatives (FS1), and L2 speakers who produced longer voiced than voiceless fricatives (FS2).

Table 5. Fricative duration in a FOD context and grouping of participants. Native-like values marked in yellow.

Fricative Duration		_##		**Difference**
		/z/	/s/	
NS	**AM**	242.6	301.2	58.6
	J	152.7	190.7	38
FS1	**JUD**	121.2	153.5	32.3
	JC	202.5	224.3	21.8
	AB	136.7	155.1	18.4
FS2	**AS**	218.5	207.8	-10.7
	CL	132.4	118.7	-13.7
	MX	195.1	180.2	-14.9
	ST	178.5	161	-17.5
	ER	156.6	126	-30.6
	NR	174.3	135.4	-38.9

Although there is interspeaker variation within the NS group, both native speakers followed the expected values: AM produced voiceless fricatives 58.6 ms longer than voiced fricatives; J produced voiceless fricatives 38 ms longer than their voiced counterpart (see Figures 15, 16), in line with the values reported by Klatt.

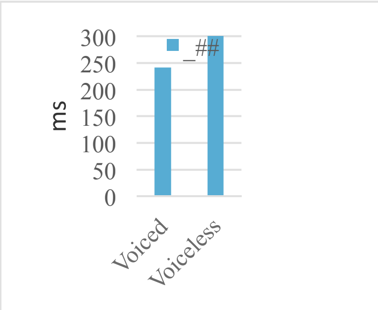

Figure 15. Fricative duration in final position for NS speaker AM.

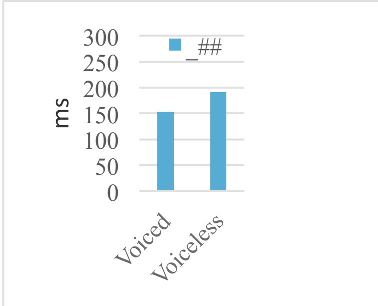

Figure 16. Fricative duration in final position for NS speaker J.

In FS1 we find three speakers, AB, JC, and JUD. The latter is the one who approximated the most to the targeted values (/s/ is 32.2 ms longer than /z/) (see Figure 17). AB and JC produced longer voiceless than voiced fricatives by 21.8ms and 18.4 ms respectively. Although they do not achieve native-like values, participants in this group produce longer voiceless than voiced fricatives in final position.

FS2 is composed by the rest of the participants (AS, NR, ER, MX, CL, ST). These participants all have negative values (see Table 4), i.e., their voiceless fricatives are shorter than their voiced fricatives. NR presented the largest (negative) difference in duration: voiceless obstruents are 38.9 ms shorter than the voiced obstruents (see Figure 18), and AS the smallest, -10.7 (see Fig 19).

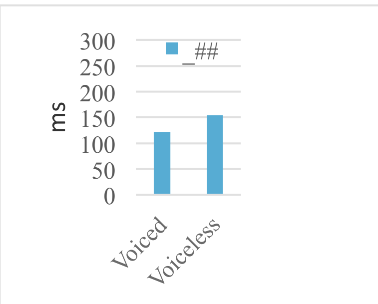

Figure 17. Fricative duration in final position for FS1 speaker JUD.

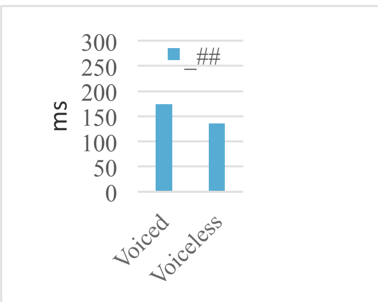

Figure 18. Fricative duration in final position for FS2 speaker NR.

Figure 19. Fricative duration in final position for FS2 speaker AS.

4.2 Regressive Voicing Assimilation (RVA)

4.2.1 Preceding Vowel Duration

On the basis of the results obtained, participants were grouped as follows: native speakers (NS), L2 speakers of English who produced a native-like voiced-to-voiceless ratio (≥1.25) in at least three contexts (FS1), L2 speakers who produced the correct ratio in two context (FS2), and speakers who produced the a native-like ratio in only one context (FS3) (See Table 5).

Table 6. Preceding vowel duration in a RVA context and grouping of participants. Correct ratios marked in yellow.

Preceding Vowel Duration		_C [-voice]	_C [+voice]	_N	_V
NS	**AM**	1.44	1.54	1.2	1.53
	J	1.35	1.58	1.76	2.37
FS1	**AB**	1.42	1.19	1.34	2.06
	JUD	1.28	1.25	1.25	0.95
	ST	1.3	1.14	1.38	1.56
FS2	**NR**	1.34	1.04	1.25	1.07
	CL	1.11	1.21	1.67	1.71
FS3	**MX**	0.84	1.03	1.1	1.31
	JC	1.27	1.11	1.16	1.2
	ER	0.89	0.97	1.13	1.46
	AS	1.26	0.84	0.83	0.95

Group NS includes native speakers AM and J. The former presents the expected voiced-to-voiceless ratio (≥1.25) in all contexts (1.44 before a voiceless consonant (_C$_{[-voice]}$) (e.g. *jazz-club, class president*), 1.54 before a voiced consonant (_C$_{[+voice]}$) (e.g. *jazz-rock, classroom*), and 1.53 before a vowel (_V)) (e.g. *jazz-addict, class attendance*), except before a nasal (_N), ratio 1.2 (e.g. *jazz musician, class mates*). J, however, has a ratio larger than 1.25 in all contexts: 1.35 in _C$_{[-voice]}$, 1.58 in _C$_{[+voice]}$, 1.76 in _N, and 2.37 in _V (see Figures 21, 22). As we can see in figures 20 and 21, J has in general longer vowels than AM. Despite this variation, the results are consistent with those found in the literature.

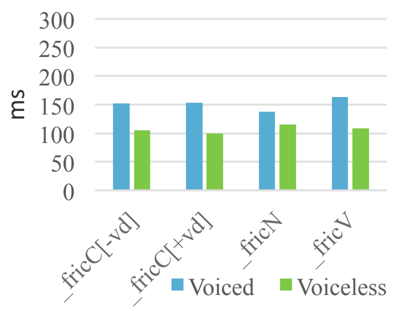

Figure 20. Mean vowel duration of /z/ and /s/ in different contexts for NS speaker AM.

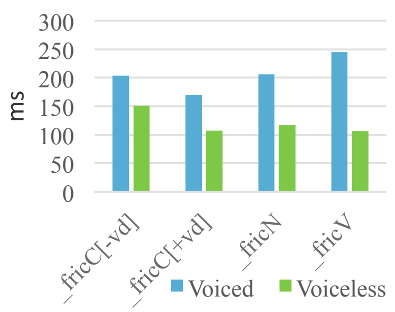

Figure 21. Mean vowel duration of /z/ and /s/ in different contexts for NS speaker J.

FS1 includes non-native speakers AB, JUD and ST. They produced native-like voiced-to-voiceless ratios in three of the four contexts. AB has a ratio of 1.42 in $\_C_{[-voice]}$, 1.34 in _N, and 2.06 in _V. However, the ratio before in $\_C_{[+voice]}$ is 1.19. ST behaved similarly to AB: we find correct ratios (1.30, 1.38, and 1.56) in all contexts except for those followed by a voiced consonant (1.14) (see Figures 22, 23). JUD presents vowel ratios of 1.28 in $\_C_{[-voice]}$, 1.25 in $\_C_{[+voice]}$, and 1.25 in _N produced longer, rather than shorter, vowels before voiceless fricatives when followed by a vowel (0.95 ratio).

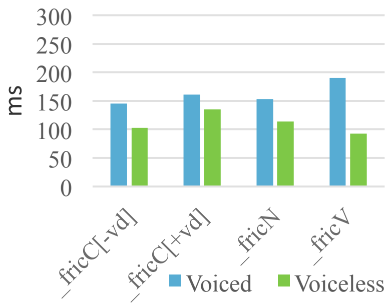

Figure 22. Mean vowel duration of /z/ and /s/ in different contexts for FS1 speaker AB.

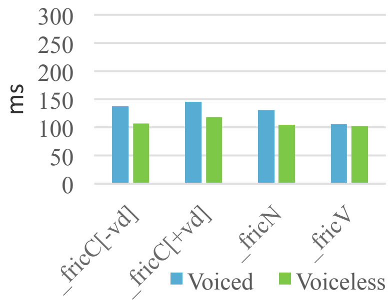

Figure 23. Mean vowel duration of /z/ and /s/ in different contexts for FS1 speaker JUD.

FS2 is composed by two participants, CL and NR. The former presented native-like values when preceding a nasal (1.67) and a vowel (1.71). CL, however, did not behave native-like in context where /z/ and /s/ where followed by a consonant (1.11 in $\_C_{[-voice]}$, 1.21 in $\_C_{[+voice]}$) (see Figures 24, 25). NR produced native-like values in $\_C_{[-voice]}$ (1.34) and _N (1.25). This participant, however, presented ratios lower than 1.25 (1.04, 1.07) in $\_C_{[+voice]}$ and _V.

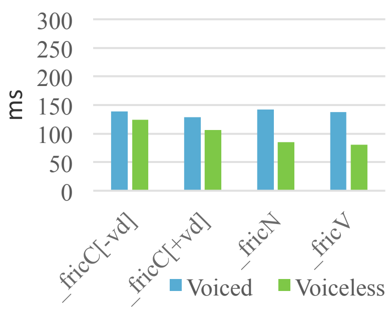

Figure 24. Mean vowel duration of /z/ and /s/ in different contexts for FS2 speaker CL.

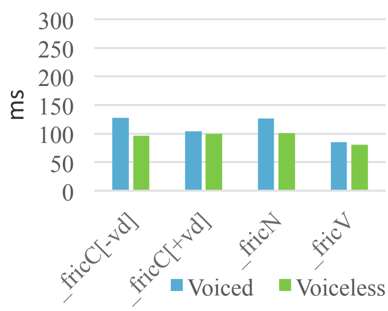

Figure 25. Mean vowel duration of /z/ and /s/ in different contexts for FS2 speaker NR.

Participants MX, ER, JC, and AS conform the last group, FS3. These participants presented only one correct voiced-to-voiceless ratio. Both MX and ER succeed in _V contexts (1.31, 1.46 respectively), whereas JC and AS succeeded in $\_C_{[-voice]}$ contexts (1.27, 1.26 respectively). None of these participants produced correct voiced-to-voiceless ratios when fricatives where followed by a nasal or a voiced consonant. Moreover, speakers in group FS3, except for JC, produced, at least, one token where vowels were longer when preceding a voiceless than a voiced fricative. As a matter of fact, AS shows longer vowels in _/s/ in all contexts, except $\_C_{[-voice]}$: 0.84 in $\_C_{[+voice]}$, 0.83 in _N, and 0.95 in _V.

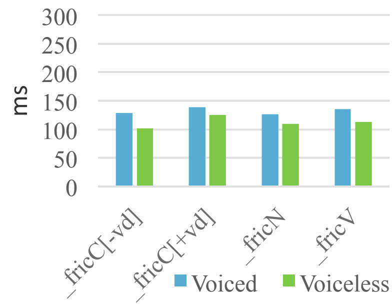

Figure 26. Mean vowel duration of /z/ and /s/ in different contexts for FS3 speaker JC.

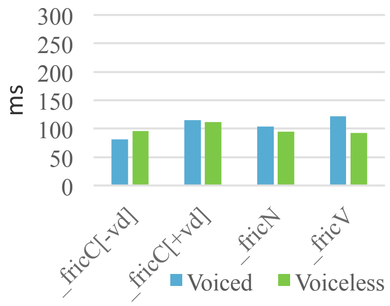

Figure 27. Mean vowel duration of /z/ and /s/ in different contexts for FS3 speaker MX.

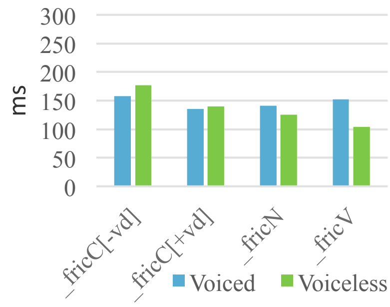

Figure 28. Mean vowel duration of /z/ and /s/ in different contexts for FS3 speaker ER.

4.2.2 Voicing during the Fricative

Voicing during the fricative is the most salient cue to voicing assimilation. A look at the measurements obtained suggested four patterns: native speakers (NS), L2 speakers of English who behave native-like (FS1), L2 speakers who show a difference in voicing between voiced and voiceless fricatives, although they produce a greater amount of voicing in /s/ than NS —partial voicing assimilation— (FS2), and L2 speakers who show full voicing assimilation (FS3) (see Table 7).

Voicing during fricative (%)		_C[-voice]		_C[+voice]		_N		_V	
		/z/	/s/	/z/	/s/	/z/	/s/	/z/	/s/
NS	AM	93	21	100	4	100	9	100	7
	J	34	13	29	0	38	15	90	11
FS1	**ER**	25	13	20	16	100	6	100	11
FS2	**AB**	30	17	52	17	51	17	60	100
	JC	13	8	23	9	75	13	100	62
	NR	49	23	45	23	80	63	58	67
FS3	**CL**	8	14	17	30	90	13	24	84
	JUD	15	13	100	100	100	14	38	43
	MX	18	20	21	13	33	45	61	100
	ST	50	51	93	100	100	100	100	100
	AS	7	7	5	10	9	9	100	84

Table 7. Fricative voicing in RVA contexts and grouping of participants. Correct voicing marked in yellow.

Native speakers in the NS group are AM and J. AM presents an average of 63.3 ms, 73 ms, 55 ms, and 110.7 ms of voicing in /z/, and of 13.7 ms, 5.7 ms, 7.4 ms, and 6.3 ms for /s/ when followed by a voiceless consonant, a voiced consonant, a nasal, and a vowel respectively. J does not show as much voicing as AM across all contexts. We find an average of 23 ms, 31 ms, 23.3 ms, and 60.7 ms for /z/ and an average of 113 ms, 0 ms, 18 ms, and 11 ms for /s/ in $\_C_{[-voice]}$, $\_C_{[+voice]}$, _N, and _V respectively. The amount of voicing found in voiceless fricatives —which is not superior than 20 ms in any sequence— can be attributed to voicing continuation. In Figures 29 and 30 we can see the percentage of voicing for voiced and voiceless stops in the different context for each participant of this group. As expected, despite difference across speakers, the same pattern of voicing is maintained.

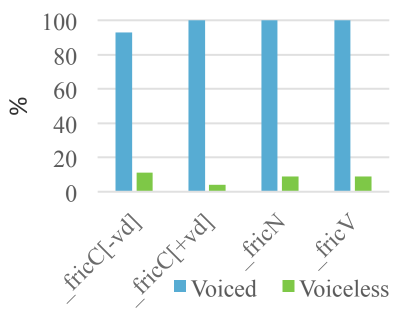

Figure 29. Percentage of voicing for NS speaker AM.

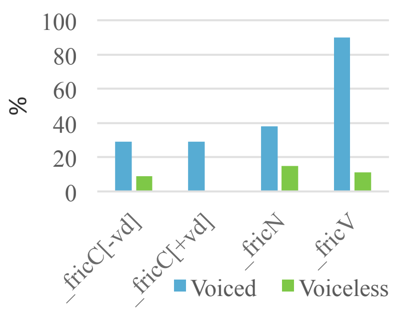

Figure 30. Percentage of voicing for NS speaker J.

ER is the only L2 speaker of English who achieved a close-to-native production of voicing patterns (group FS1). We find an average period of voicing in voiceless fricatives of 13 ms in _C$_{[-voice]}$, 18 ms in _C$_{[+voice]}$, 3 ms in _N, and 8 ms in _V; and an average period of voicing in voiced fricatives of 20 ms, 30 ms, 50 ms, and 61 ms respectively. Furthermore, this participant produced in a native-like manner the period of voicing continuation in /s/, under 20 ms, which cannot be argued to be produced purposefully. In Figure 31 we can see how ER presents 100% of voicing in /z/ when followed by nasal and a vowel —following a similar pattern of that of NS AM—, whereas only 25% and 20% when followed by obstruents —a similar pattern to that of NS J in such contexts—.

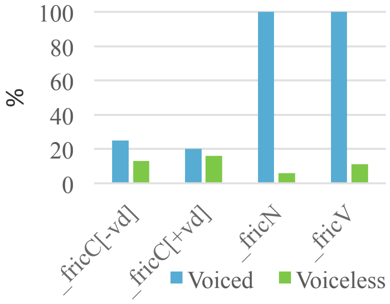

Figure 31. Percentage of voicing for FS1 speaker ER.

FS2 includes by speakers AB, JC, and NR. Overall, this group presents higher degree of voicing in voiceless fricatives than NS and FS1 do, especially when followed by a vowel: 100%, 62%, and 67% respectively (native-like values in this context range from 7 to 11%). Moreover, AB and NR present a higher percentage of voicing in /s/ than in /z/ when followed by a vowel (_V). We could argue that these participants show voicing assimilation in such context. Also, participant NR shows 63% of voicing in /s/_N, an amount of voicing that cannot be attributed to voicing continuation (see Figure 32). In the other contexts, however, these three speakers do not show voicing assimilation.

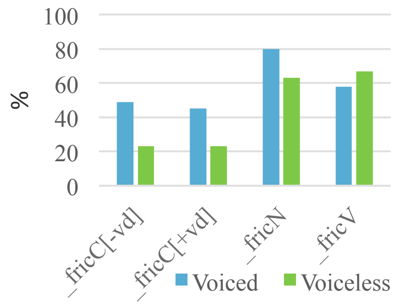

Figure 32. Percentage of voicing for FS2 speaker NR.

Participants AS, CL, JUD, MX, and ST conform FS3. Within this group we can find different patterns. Three participants —AS, CL, and JUD— showed the correct voicing in one context, whereas MX and ST failed to produce the correct voicing pattern in all contexts. In Figure

33 we can observe a pattern found in two of the participants of this group (CL, JUD) where there is complete voicing assimilation in all contexts except when the fricative is followed by a nasal. AS (Figure 34), on the other hand, showed complete voicing assimilation in all contexts (7% in /z/ and 0% in /s/ in $\_C_{[-voice]}$, 5% in /z/ and 10% in /s/ in $\_C_{[+voice]}$, and 9% in both fricatives in _N) except when the fricative is followed by a vowel (100% in /z/, 84% in /s/). Lastly, in Figure 35 we can observe the pattern found in the two remaining participants (ST, MX). In this case, voicing assimilation clearly takes place across contexts. ST presented full voicing in both /z/ and /s/ in all contexts, except in _C[-voice], where both fricatives show 50% of voicing (Figure 35).

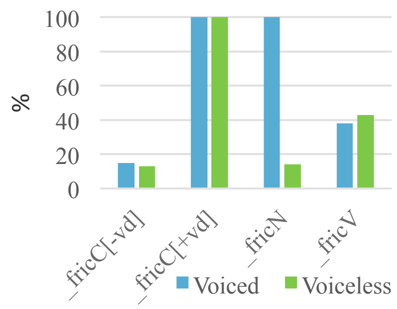

Figure 33. Percentage of voicing for FS3 speaker JUD.

4.2.3 Fricative Duration

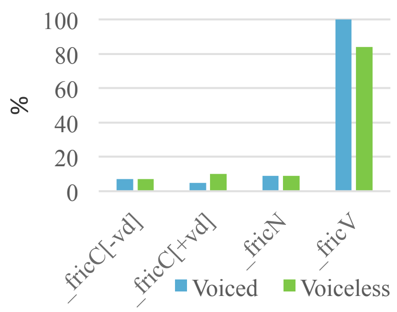

Figure 34. Percentage of voicing for FS3 speaker AS.

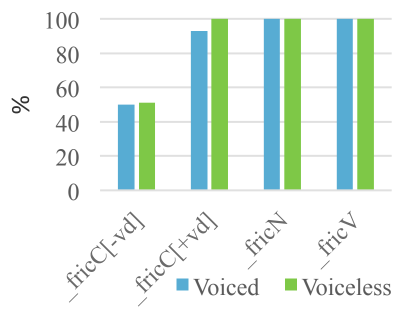

Figure 35. Percentage of voicing for FS3 speaker ST.

As stated in section 4.1.3, voiceless fricatives tend to be approximately 40 ms longer than voiced fricatives in English. Native speakers AM and J showed slightly small differences in medial fricatives (25.5 and 28 ms respectively). None of the L2 speakers of English produced a similar difference in fricative duration to cue voicing. Therefore, the nine non-native speakers were placed in the same group. (See Table 8).

Fricative Duration		_C[-voice]		_C[+voice]		_N		_V		**Average difference**
		/z/	/s/	/z/	/s/	/z/	/s/	/z/	/s/	
NS	**AM**	68	94	72	126	55	84	82	69	25.5

	J	74	71	104	144	72	116	68	102	28
FS1	**CL**	74	77	107	104	60	37	50	125	13.59
	AS	72	85	80	110	87	63	52	49	0.22
	ER	97	81	111	147	78	67	69	60	0.03
	JUD	73	51	91	89	63	73	89	75	-6.6
	MX	100	97	127	113	84	93	88	66	-7.2
	ST	94	65	145	133	53	74	88	71	-9
	JC	94	60	104	105	88	79	75	78	-9
	NR	112	88	112	130	96	86	106	82	-11
	AB	88	65	80	98	138	62	56	45	-23.21

Table 8. Fricative duration in RVA contexts and grouping of participants. Native-like values marked in yellow.

NS includes by native speakers AM and J, who, again, served as control group. AM presented an average difference between /z/ and /s/ of 25.5 ms, i.e., he produced voiceless fricatives an average of 25.5 ms longer than voiced fricatives. J presented a similar pattern: her voiceless fricatives were an average of 28 ms longer. However both native speakers showed instances where /z/ was slightly longer than /s/ (_V, _$C_{[-voice]}$ respectively), though these differences were not significant (see Figures 36 and 37).

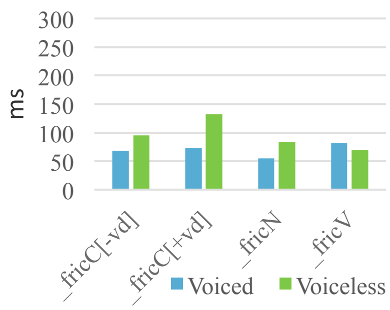

Figure 36. Total fricative duration for NS speaker AM.

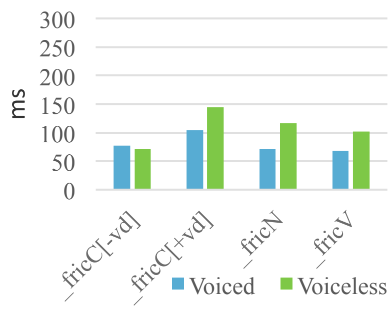

Figure 37. Total fricative duration for NS speaker J.

FS1 includes by the rest of non-native speakers, who show different patterns. AS is the only participant who shows fricative duration in the right direction in two contexts: when fricatives are followed by a voiceless consonant (13.4 ms of difference), and when followed by a voiced consonant (15.4 ms of difference). On one hand, there are five of the eight participants in this group who showed a voiceless to voiced difference in the right direction in one context. Within this subgroup, three participants —NR, AB, ER— succeeded when fricatives preceded a voiced consonant (e.g. *classroom*, *jazz-rock*). The other two participants, CL and ST, succeeded when fricatives preceded a vowel (difference of 75 ms) and a nasal (difference of 21 ms) respectively. On the other hand, there are three participants who fail to show a significant difference between voiced and voiceless fricatives in all contexts (JC, JUD, and MX). These participants show an average difference between /s/ and /z/ of -9 ms, -6.6 ms, and 7.2 ms respectively. The negative values indicate that, in these cases, voiced fricatives are longer than voiceless fricatives (see Table 7 and Figures 38-41).

T-tests were run on the raw data for those sequences where these participants showed longer

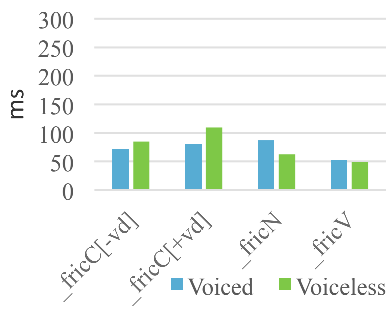

Figure 38. Total fricative duration for FS1 speaker AS.

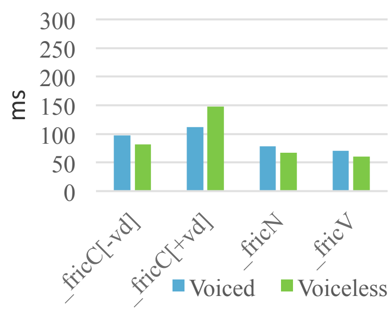

Figure 39. Total fricative duration for FS1 speaker ER.

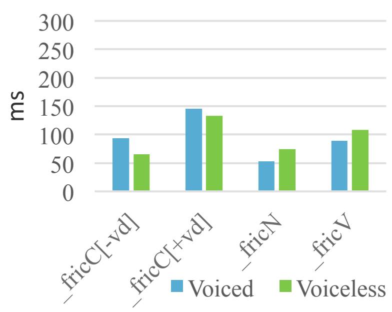

Figure 40. Total fricative duration for FS1 speaker ST.

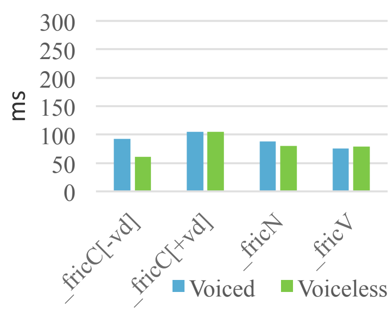

Figure 41. Total fricative duration for FS1 speaker JC.

voiceless fricatives. The tests confirmed that the difference in ms in those tokens is not statistically significant ($p > 0.05$): JC's /z/ and /s/ in _C$_{[+voice]}$ are 104 ms and 105 ms long ($t_{(5)}$=3.4, p>0.05); 75 ms and 78 ms long in _V ($t_{(5)}$=3.4, p>0.05). JUD's /z/ and /s/ in _N are 63 ms and 73 ms long

($t_{(5)}$=3.4, p>0.05). MX /z/ and /s/ in _N are 84 ms and 93 ms long ($t_{(5)}$=3.4, p>0.05). A t-test was also run for CL's voiced fricatives (74 ms) and voiceless fricatives (77 ms) in $\_C_{[-voice]}$, such difference is not statistically significant either ($t_{(5)}$=3.4, p>0.05). It can be argued, then, that those participants in this group (FS1) have not acquired fricative duration as a cue for fricative voicing.

5. Discussion

The results for Final Obstruent Devoicing will be discussed first, followed by those for Regressive Voicing Assimilation. Concerning FOD, there is only one participant, AB, who seems to have acquired the voicing distinction in final fricatives in English, in other words, he does not show FOD. AB presents a vowel duration voiced-to-voiceless ratio larger than 1.25, presents also devoicing of final obstruents maintaining the voicing contrast between voiced and voiceless fricatives, though not with the same magnitude as English speakers, and his /s/s are longer than his /z/s.

There are two participants who master two cues out of the three. On one hand we have JUD, who belongs to FS2 in preceding vowel duration, and FS1 in both fricative voicing and total fricative duration. This means this participant has mastered the cues for fricative voicing except for the vowel duration voiced-to-voiceless ratio, which is below 1.25 (1.13). There is, therefore, negative transfer from the L1 in this aspect. On the other hand we find ST, who belongs to FS1 in both preceding vowel duration and fricative voicing, but FS2 in total fricative duration, given that voiceless fricatives is 17.5 ms shorter than voiced fricatives.

Three participants master only one cue. On one hand, CL and ER, only master fricative voicing (FS1). These participants failed to produce a native-like vowel duration ratio (1.15 and 1.09 respectively) (FS2) as well as longer voiceless fricatives in respect to voiced fricatives (-13.7 ms and -30.6 ms respectively) (FS2). This suggests that only voicing of the obstruent is employed to cue voicing. There is negative transfer from the L1, given that in Catalan neither preceding vowel length nor fricative duration are employed to cue voicing. These speakers, however, manage to keep final /s/ and /z/ different in terms of voicing during the fricative, which may not be a sufficient cue to indicate voicing to English ears. On the other hand, JC only masters fricative duration (FS1), whereas preceding vowel duration and voicing of the fricative are not mastered (FS2) and hence not used as cues for voicing. JC produces voiceless fricatives an average of 21.8 ms longer than their voiced counterpart, exhibiting a native-like pattern. However, her voiced to voiceless ratio is 1.17, which, while it is produced in the right direction, it is not sufficient. The participant also presents complete assimilation of /z/ and /s/ in final position (5% and 6% of voicing respectively).

Lastly, participants AS, MX, and NR have not mastered any cue to distinguish voiced and voiceless fricatives in a context of FOD. On one hand, AS shows a voiced to voiceless ratio of 0.83 (FS3), that is, vowels are longer when followed by voiceless fricatives. AS also fails to make a difference in voicing between /z/ and /s/ in final position (3% of voicing in both contexts) and to produce longer voiceless fricatives in respect to voiced fricatives. On the other hand, MX and NR present the same grouping pattern. Regarding vowel length, they both show ratios in the right direction (1.16 and 1.15), that is, their vowels are indeed longer before a voiced fricative, but the difference produced is not enough (<1.25). Concerning voicing during the fricative, both participants present complete voicing assimilation: NR has 12% of voicing in /z/ while 11% in /s/; MX has 6% and 5% of voicing respectively. In terms of fricative duration, both present negative values (-39, -15), i.e., longer voiced fricatives than voiceless fricatives.

Relative RVA, contrary to the data obtained for FOD, we do not have instances where participants master the three cues used by native English speakers. Participants AB, ER, JUD, and ST appear to master one cue. AB, JUD, and ST seem to master preceding vowel duration to indicate voicing, presenting ratios longer than 1.25 (average ratios of 1.5, 1.18[1], and 1.34 respectively) in at least three contexts. Given that they master neither voicing during fricative nor fricative duration, preceding vowel duration is the only cue employed by these speakers to indicate fricative voicing.

[1]The 1.18 ratio, which may not be considered native-like, is due to the effect of ratio of 0.95 in one particular context, _V, by speaker JUD. In all other contexts her ratios are > 1.25.

ER, although sounding near-native to English ears, only masters voicing during fricative: the data obtained for this cue shows the same pattern as those of the control group (AM, J). However, this participant fails to employ vowel length (FS3, average ratio of 0.97) or fricative duration (FS2, average difference of 0.03 between /z/ and /s/).

According to the data gathered in this paper, the other participants of this study do not employ any of the three cues. Within this last group of speakers, however, we must make some distinctions. To begin with, NR is part of group FS2 in all cues, i.e., although she has not acquired the cues for fricative voicing, the data indicates that this participant is performing in the right direction. CL and JC perform in the right direction regarding preceding vowel duration (average ratio of 1.4) and voicing during fricative (average of 50% of voicing in /z/ and 23% in /s/) respectively, although they are part of the FS3 group in voicing during fricative (CL, average of 35% of voicing in both /z/ and /s/) and vowel length (JC, average ratio of 1.1). Neither of them seem to have acquired fricative duration as an indicator for voicing. Lastly, MX is part of group FS3 in both preceding vowel duration (average ratio of 1.07) and voicing during fricative —where she produces more voicing in /s/ (44.5%) than in /z/ (33%)—, and FS2 in fricative duration. Consequently, we can argue that this speaker has not acquired any of the cues for voicing in English.AS is the only non-native participant who shows production of fricative duration in the right direction in two contexts ($\_C_{[+voice]}$, and $\_C_{[-voice]}$). Nevertheless, this speaker presents longer vowels before voiceless fricatives (average ratio of 0.97, FS3) and complete voicing assimilation (average of 30% of voicing in /z/ and 27.5% in /s/, FS3).

Our third research question was whether or not RVA and FOD go hand in hand in the acquisition of English as an L2. Speakers AB and JUD seem to show no FOD and no RVA in most contexts. The patterns of the other speakers are more complex with FOD showing prevalence in some speakers and RVA in other speakers. Turning to the use of specific cues for each process, preceding vowel duration is the most consistent cue, i.e., eight of the nine non-native participants show the same level of mastery in both processes –whether it is the right direction or not. Fricative duration is the most inconsistent one: while some seem to be able to produce significantly longer voiceless than voiced fricatives when these appear in a context of FOD, not one participant shows such cue in RVA contexts. This results agree with those of Fullana (2008) which state that Catalan L2 speakers of English fail to use fricative duration as a cue for obstruent voicing. Except for two participants, RVA and FOD are two processes that seem to go hand in hand in L2 acquisition.

6. Conclusion

Regressive Voicing Assimilation and FOD are processes present in Catalan which tend to be transferred to English –where they do not take place– by native speakers of Catalan. It has been shown that English speakers employ preceding vowel duration, voicing during the fricative and fricative duration as cues for voicing, cues which are not present in Catalan. As we have seen in the previous section, the majority of participants present negative transfer from their L1 to their L2, failing to use all three cues. In fact, only one participant seems to master the three cues for voicing when fricatives are in final position, although he does not use them all in RVA contexts. The fact that only one (ER) of the nine non-native participants shows English native-like values in terms of voicing during the fricative, suggests that RVA does indeed occur in word-medial position.

The results of this paper support as well those obtained by Cebrian (2000) and Nobau (2017) arguing that the level of proficiency in English does not determine the mastery of the different cues native English speakers employ to cue obstruent voicing. In this case, all non-native speakers who took part in the study are advanced learners of English according to the *Straightforward Upper Intermediate and Advanced Placement Test* by Macmillan Publishers.

A significant limitation of this research has been the number of participants, both those who served as the control group and the non-native speakers. With more participants, the results of this study would have been more consistent and more representative of what role RVA and FOD play in the acquisition of English by Catalan speakers. Another factor that played a role in this paper was the prosody: it was expected that the non-native speakers would produce the correct stress pattern of the (near)minimal pairs. However, some participants pronounced the stress in compound words wrong, hence the decision to discard such tokens. Third, if the time constraint had not played a major role, I would need to further analyze the relationship between FOD and RVA in these non-native speakers. In spite of these limitations, the relationship between these two processes is an interesting topic for further research.

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8. Appendices

8.1 RVA

8.1.1 Preceding Vowel Duration

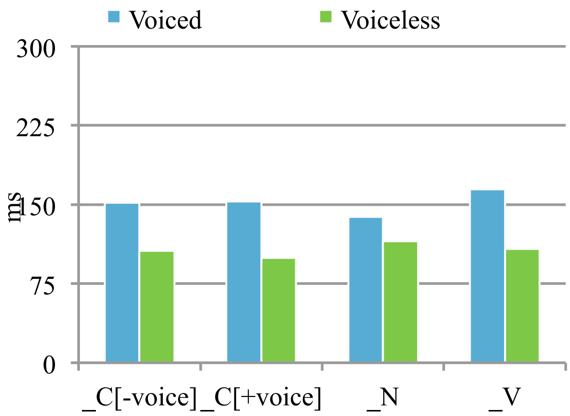

Figure 42. Mean vowel duration for NS AM.

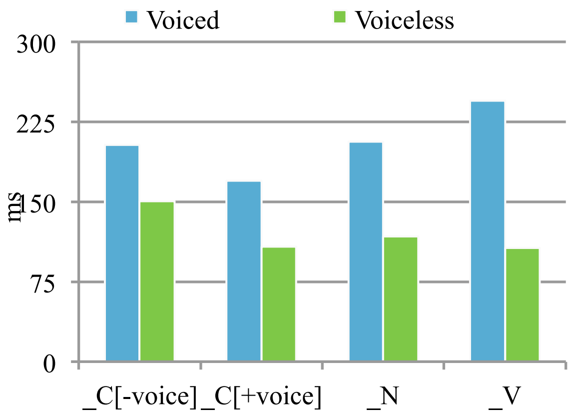

Figure 43. Mean vowel duration for NS J.

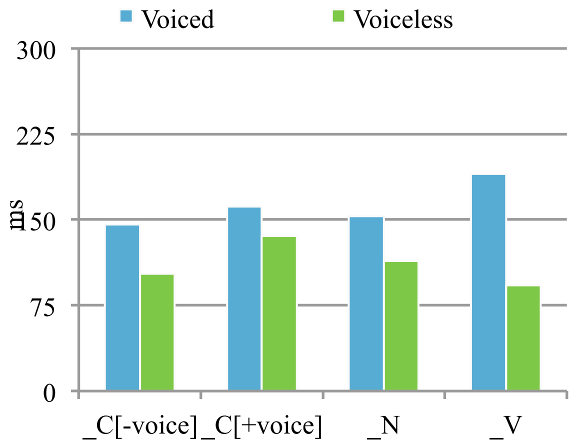

Figure 44. Mean vowel duration for NNS AB.

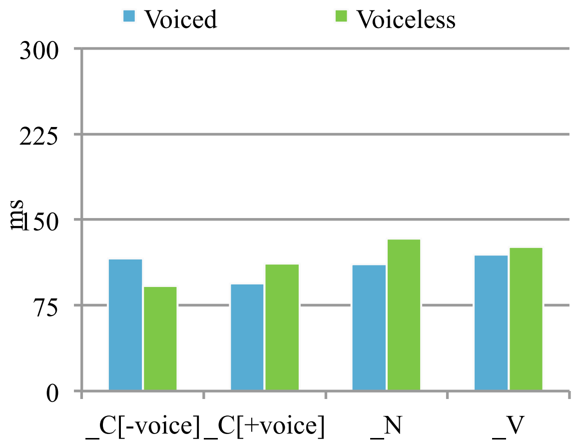

Figure 45. Mean vowel duration for NNS AS.

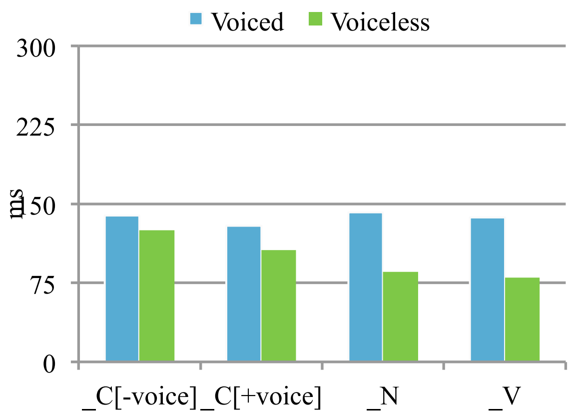

Figure 46. Mean vowel duration for NNS speaker CL.

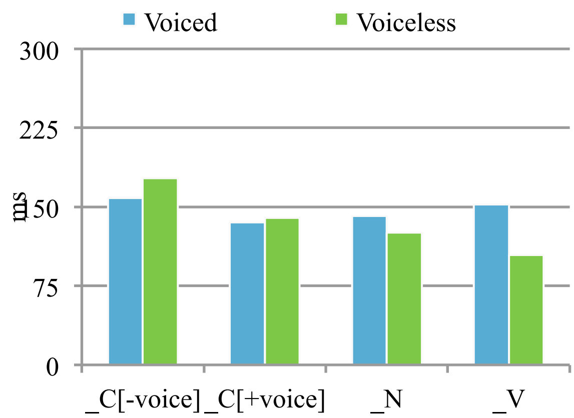

Figure 47. Mean vowel duration for NNS speaker ER.

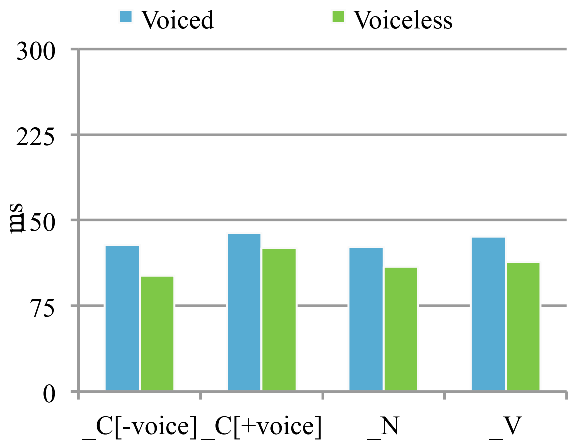

Figure 48. Mean vowel duration for NNS JC.

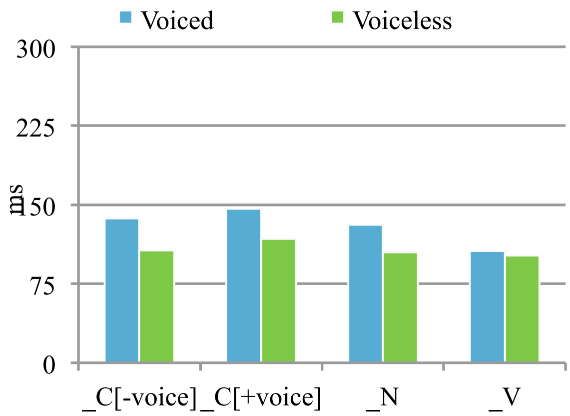

Figure 49. Mean vowel duration for NNS JUD.

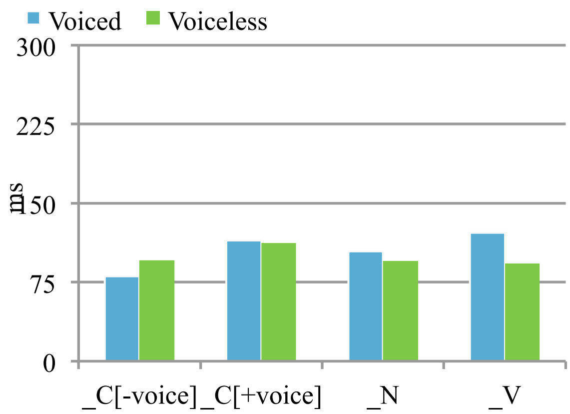

Figure 50. Mean vowel duration for NNS MX.

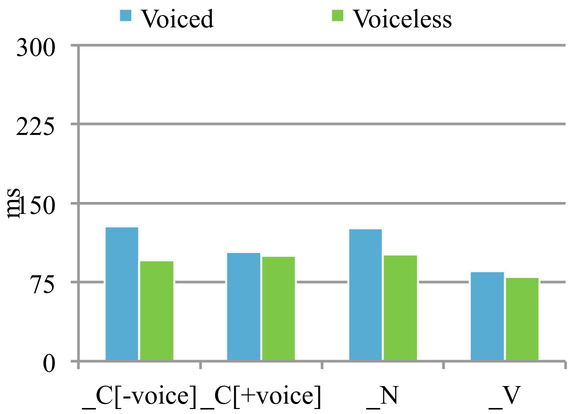

Figure 51. Mean vowel duration for NNS NR.

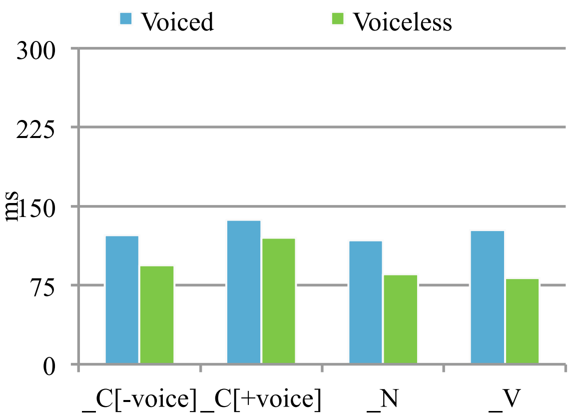

Figure 52. Mean vowel duration for NNS ST.

8.1.2 Voicing during the Fricative

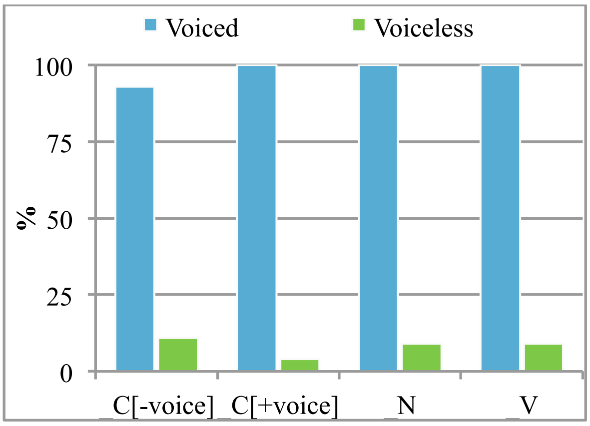

Figure 53. Percentage of voicing for NS AM.

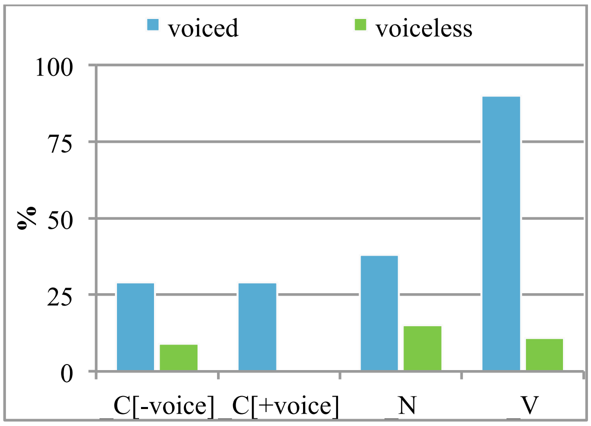

Figure 54. Percentage of voicing for NS J.

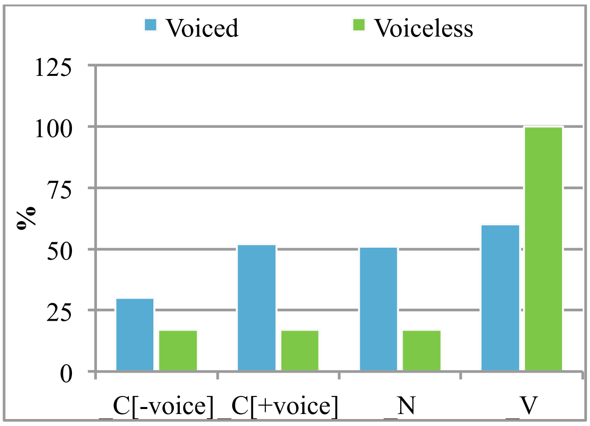

Figure 55. Percentage of voicing for NNS AB.

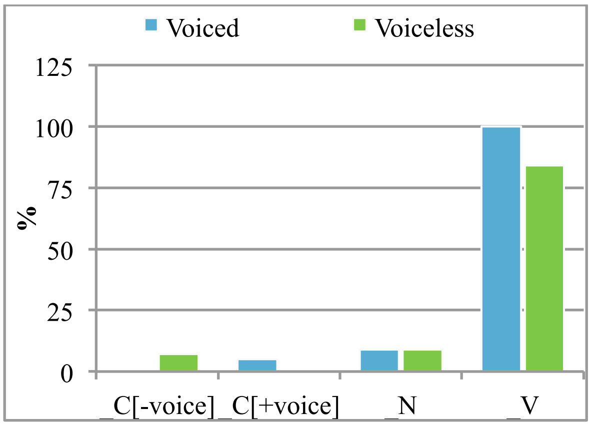

Figure 56. Percentage of voicing for NNS AS.

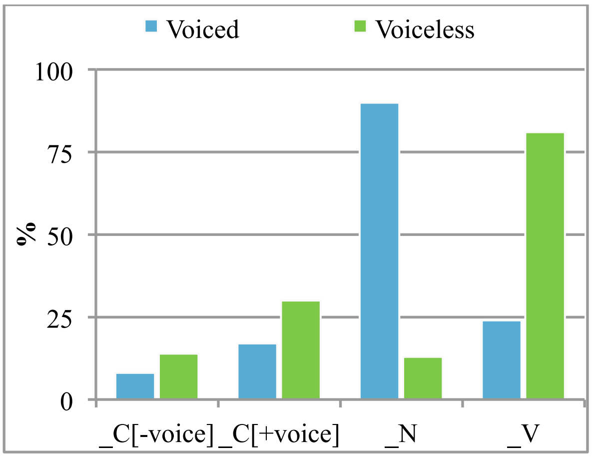

Figure 57. Percentage of voicing for NNS CL

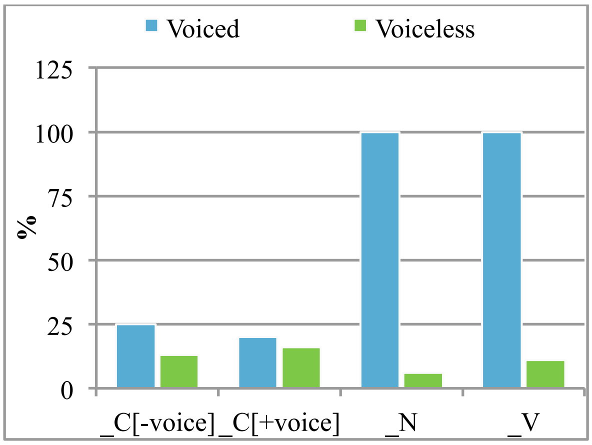

Figure 58. Percentage of voicing for NNS ER.

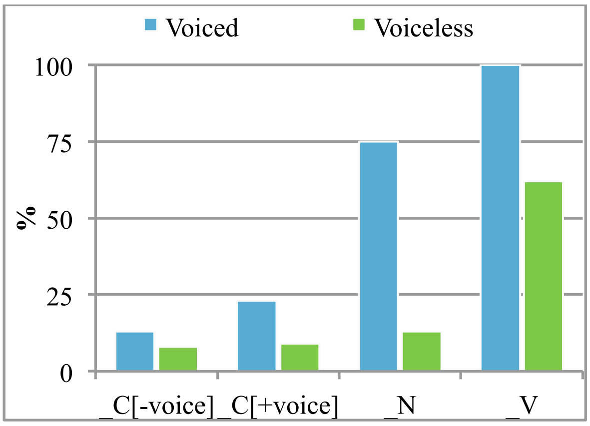

Figure 59. Percentage of voicing for NNS JC

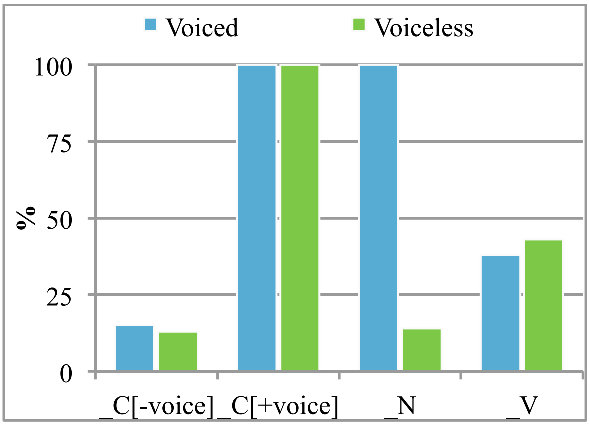

Figure 60. Percentage of voicing for NNS JUD

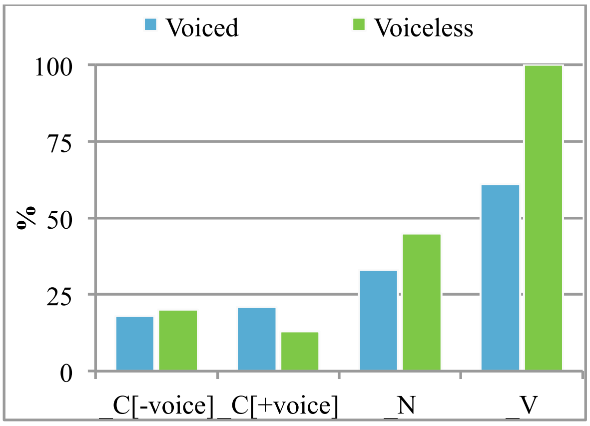

Figure 61. Percentage of voicing for NNS MX

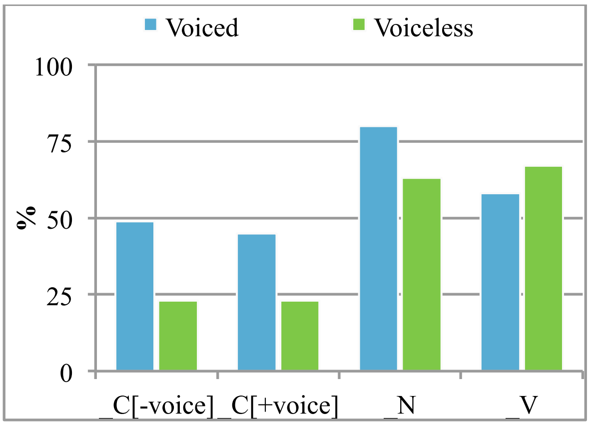

Figure 62. Percentage of voicing for NNS NR

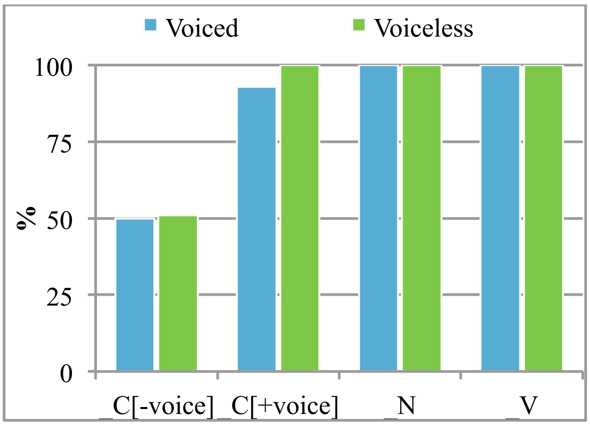

Figure 63. Percentage of voicing for NNS ST

8.1.3 Fricative Duration

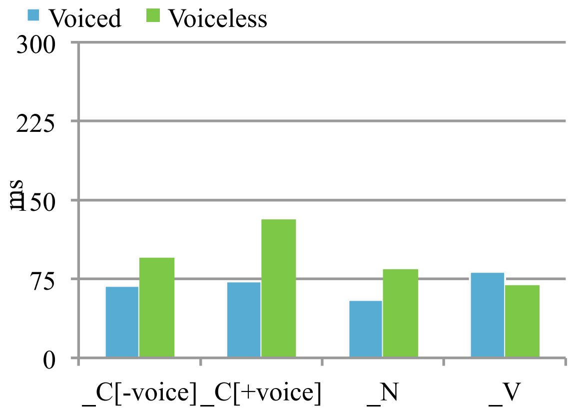

Figure 64. Fricative duration for NS AM.

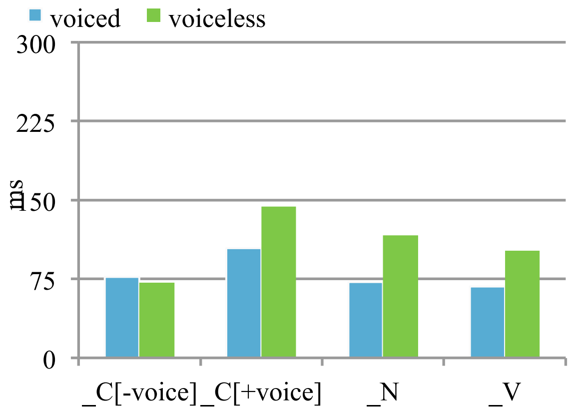

Figure 65. Fricative duration for NS J.

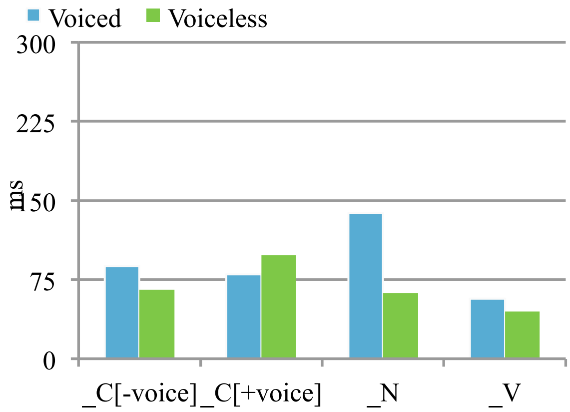

Figure 66. Fricative duration for NNS AB.

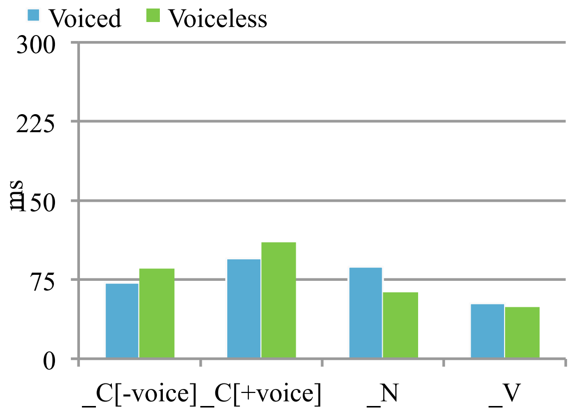

Figure 67. Fricative duration for NNS AS.

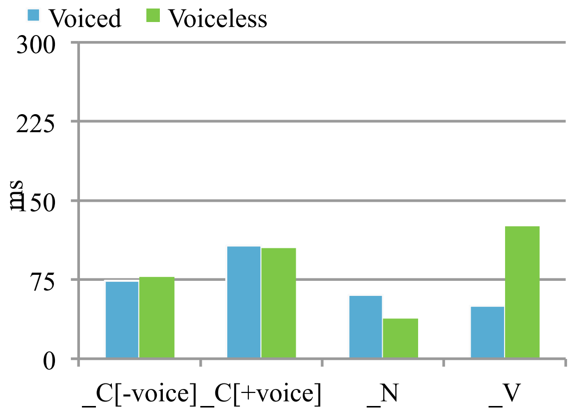

Figure 68. Fricative duration for NNS CL.

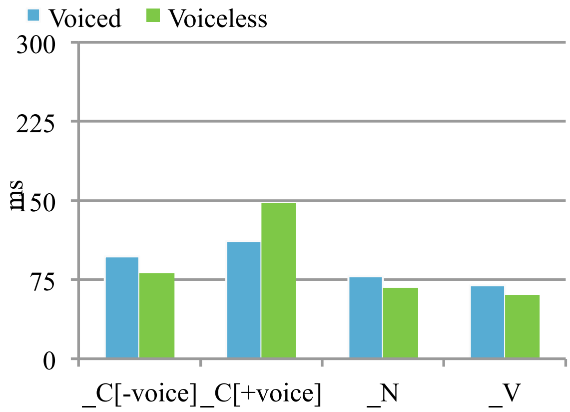

Figure 69. Fricative duration for NNS ER.

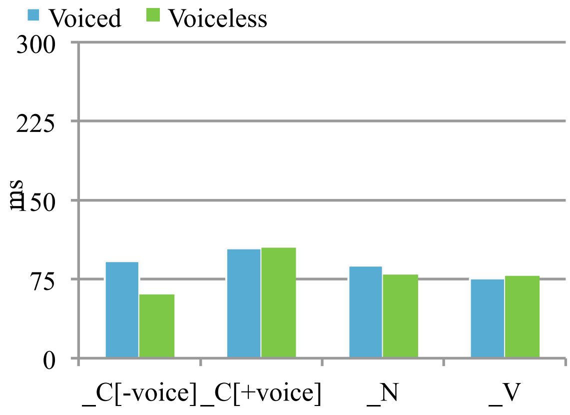

Figure 70. Fricative duration for NNS JC.

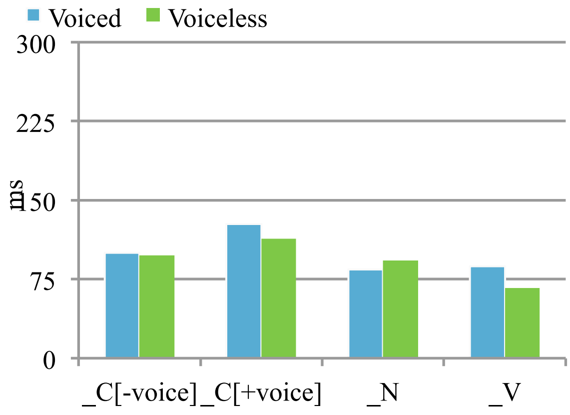

Figure 71. Fricative duration for NNS JUD.

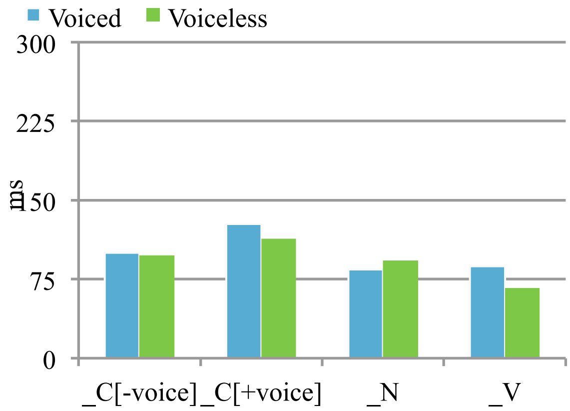

Figure 72. Fricative duration for NNS MX.

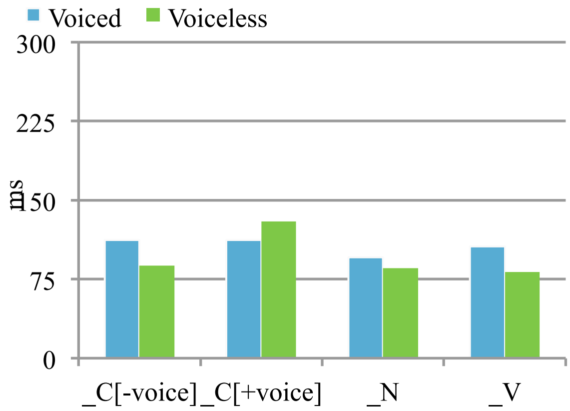

Figure 73. Fricative duration for NNS NR.

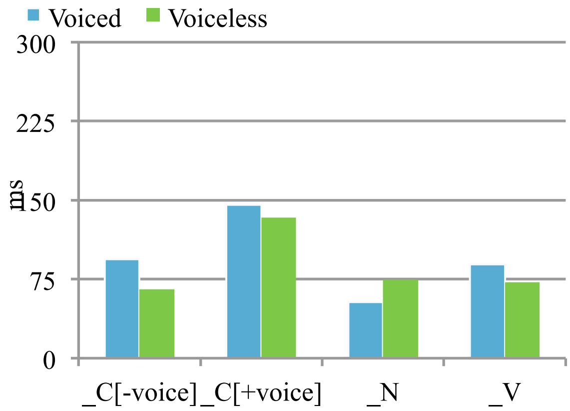

Figure 74. Fricative duration for NNS ST.

8.2 FOD

8.2.1 Preceding Vowel Duration

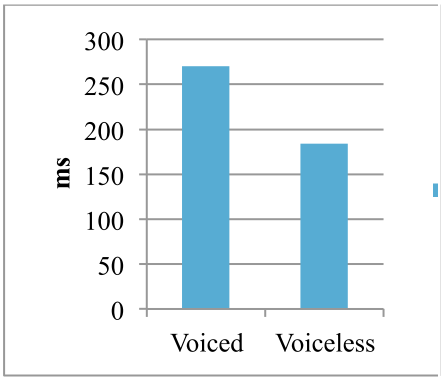

Figure 75. Preceding vowel duration for NS AM.

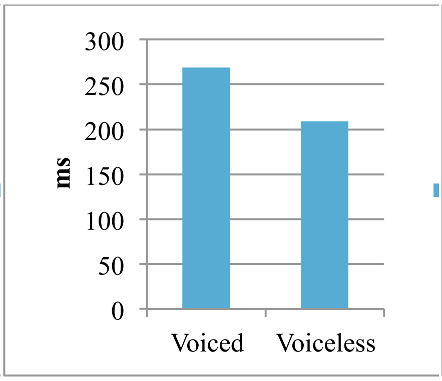

Figure 76. Preceding vowel duration for NS J.

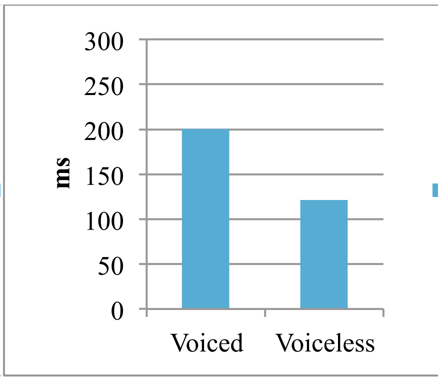

Figure 77. Mean vowel duration for NNS AB.

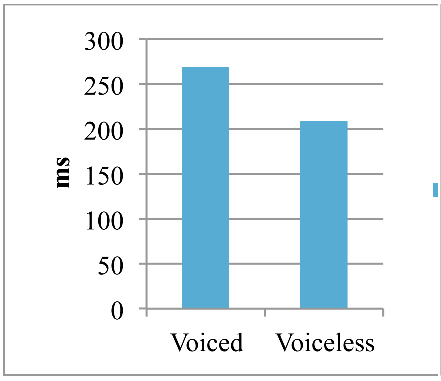

Figure 78. Mean vowel duration for NNS AS.

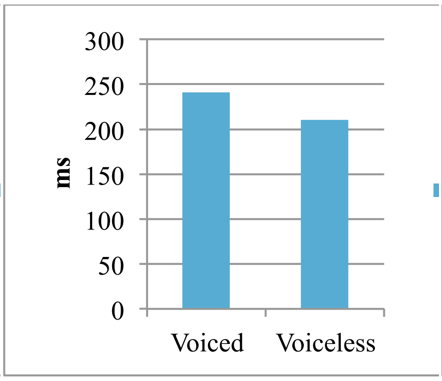

Figure 79. Mean vowel duration for NNS CL.

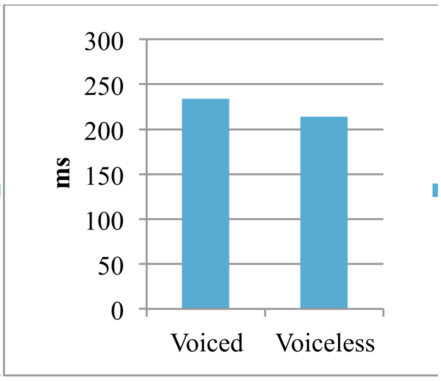

Figure 80. Mean vowel duration for NNS ER.

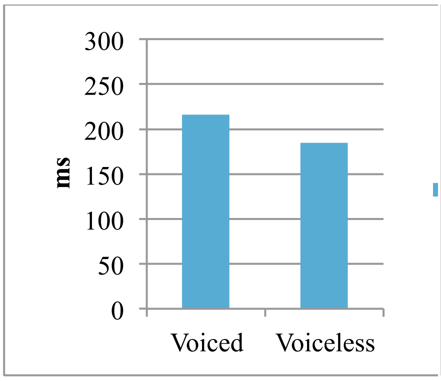

Figure 81. Mean vowel duration for NNS JC.

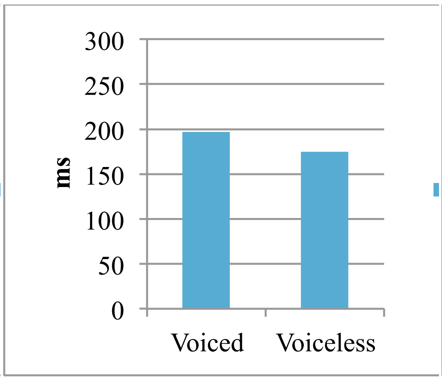

Figure 82. Mean vowel duration for NNS JUD.

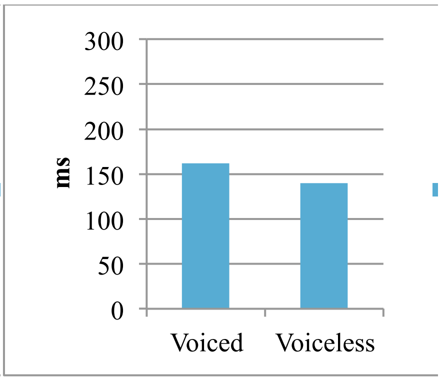

Figure 83. Mean vowel duration for NNS MX.

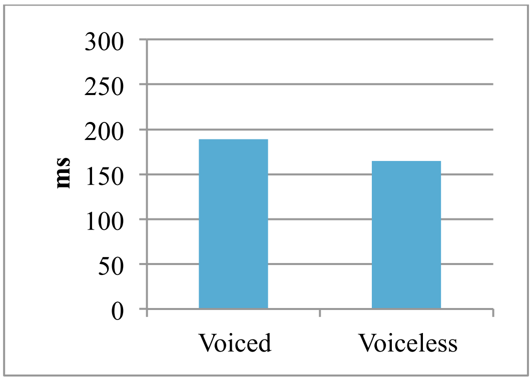

Figure 84. Mean vowel duration for NNS NR.

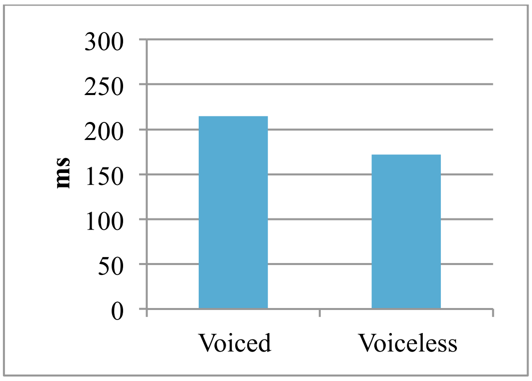

Figure 85. Mean vowel duration for NNS ST.

8.2.2 Voicing during the Fricative

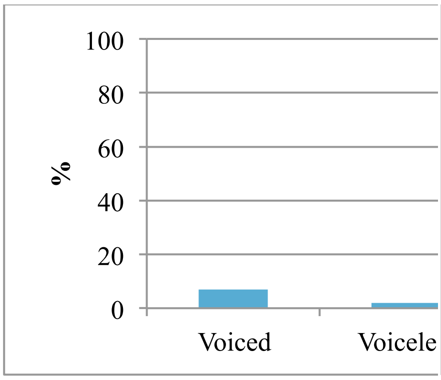

Figure 86. Percentage of voicing for NS AM.

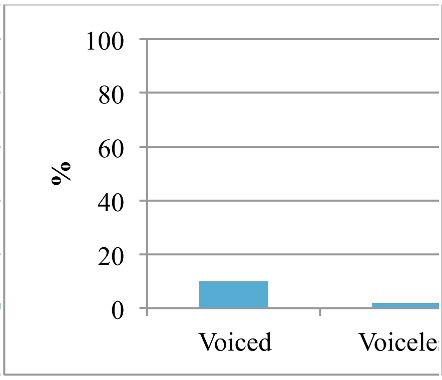

Figure 87. Percentage of voicing for NS J.

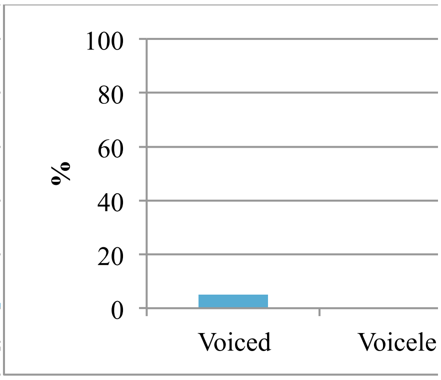

Figure 88. Percentage of voicing for NNS AB.

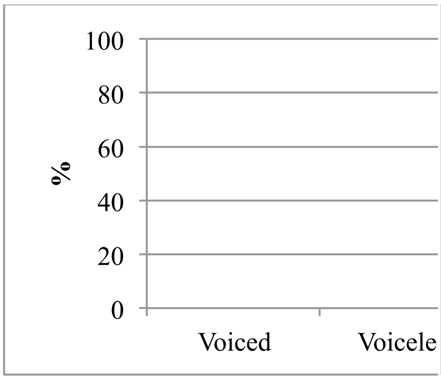

Figure 89. Percentage of voicing for NNS AS.

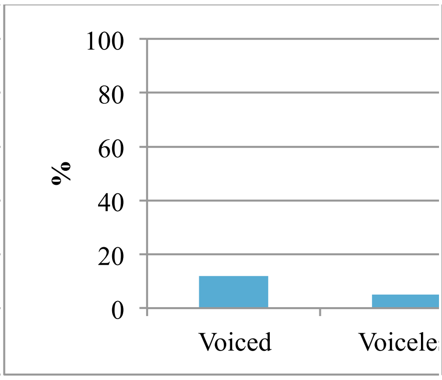

Figure 90. Percentage of voicing for NNS CL.

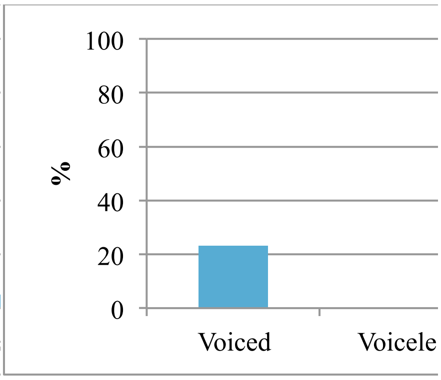

Figure 91. Percentage of voicing for NNS ER.

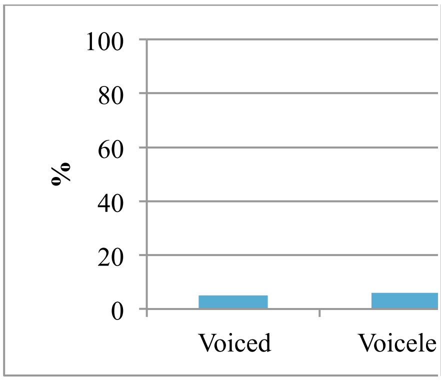

Figure 92. Percentage of voicing for NNS JC.

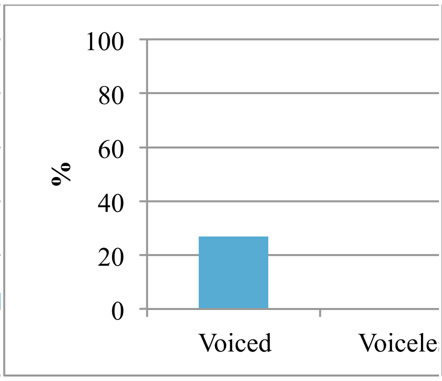

Figure 93. Percentage of voicing for NNS JUD.

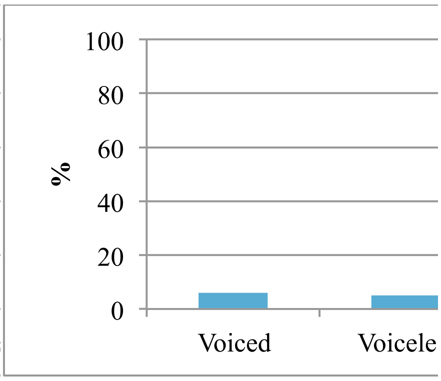

Figure 94. Percentage of voicing for NNS MX.

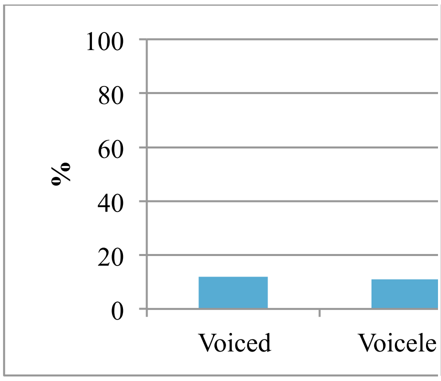

Figure 95. Percentage of voicing for NNS NR

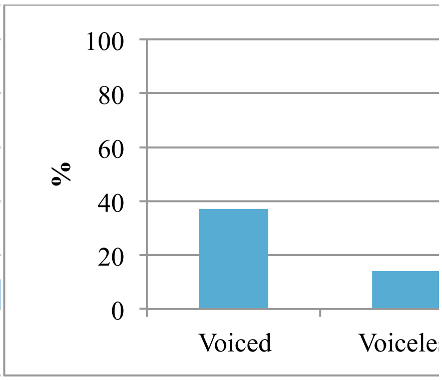

Figure 96. Percentage of voicing for NNS ST.

8.2.3 Fricative duration

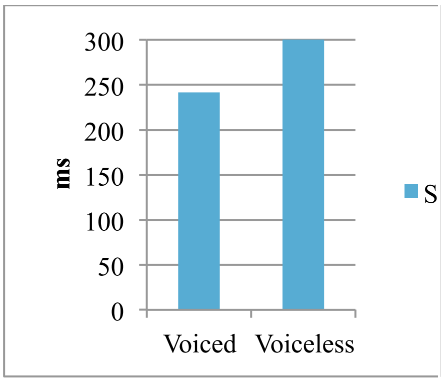

Figure 97. Fricative duration for NS AM

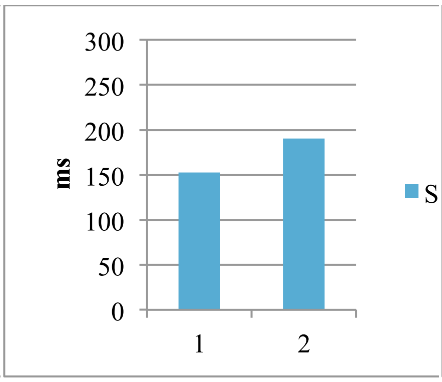

Figure 98. Fricative duration for NS J

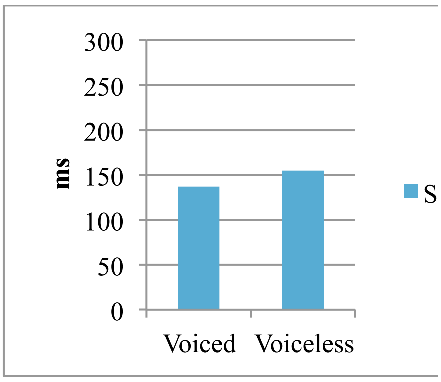

Figure 99. Fricative duration for NNS AB

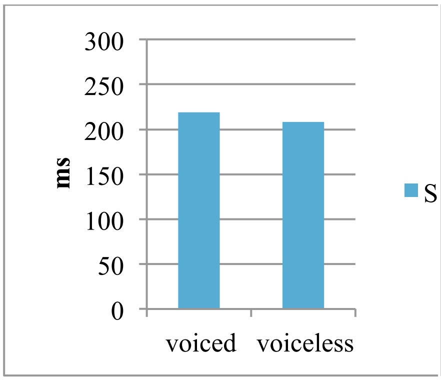

Figure 100. Fricative duration for NNS AS.

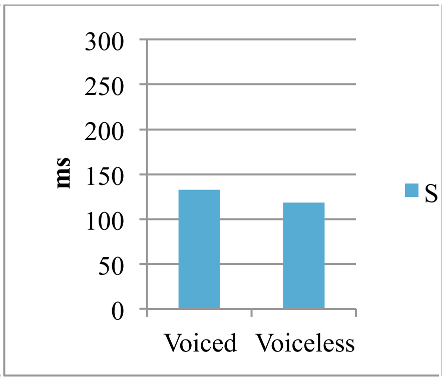

Figure 101. Fricative duration for NNS CL

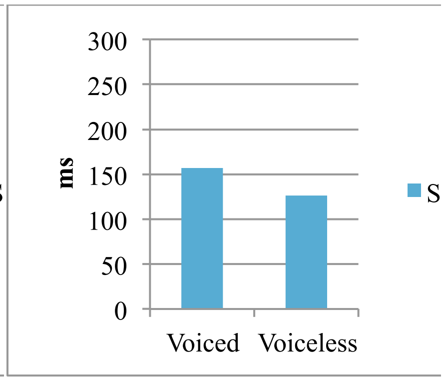

Figure 102. Fricative duration for NNS ER.

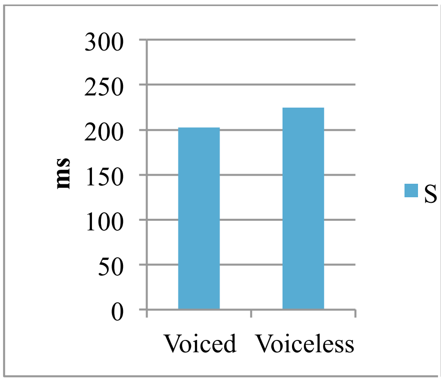

Figure 103. Fricative duration for NNS JC.

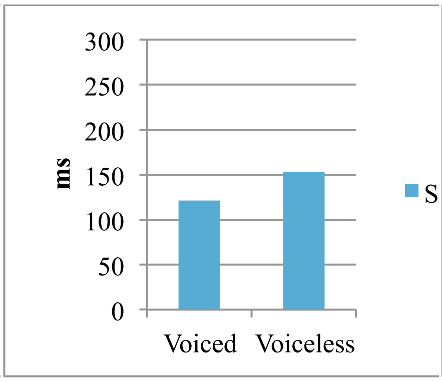

Figure 104. Fricative duration for NNS JUD.

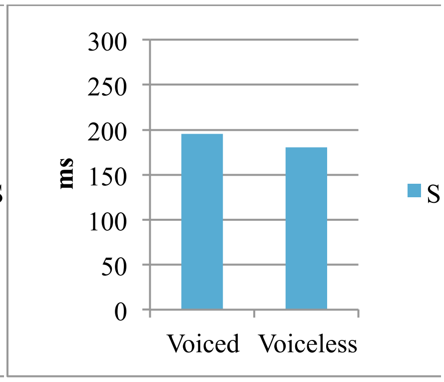

Figure 105. Fricative duration for NNS MX

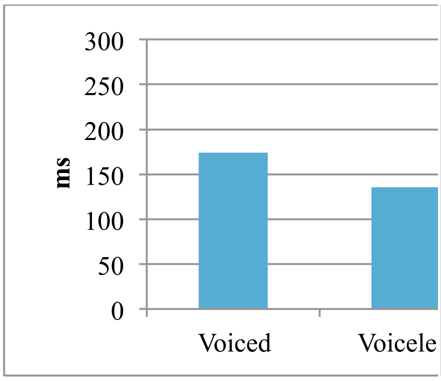

Figure 106. Fricative duration for NNS NR.

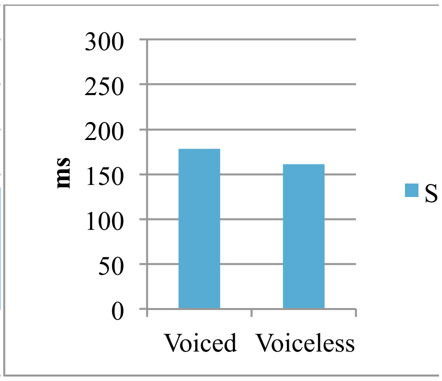

Figure 107. Fricative duration for NNS ST.