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Acoustic analysis of voiceless obstruents and nasal harmony in Desano[1]

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1. Introduction

Desano (DES) is a language of the Eastern branch of the Tukanoan family (ET) spoken in the northwestern Amazonia. DES is spoken by approximately 1,500 people in Brazil and 2,000 in Colombia (FOIRN and ISA, 2006). DES, as other ET languages, is well-known for its nasal harmony. This paper reports on an acoustic study of intervocalic voiceless stops in oral versus nasal contexts in DES and tests theoretical claims about their status.

The paper is organized as follows. In Section 2, I introduce the topic under investigation, the primary work which has motivated this study, and the background on the pattern of nasal harmony in DES. Section 3 lays out

[1] I want to thank the colleagues who attended the Conference *Structure of Amazonian Languages: Phonology and Syntax* for their comments. Special thanks to Elsa Gómez-Imbert, Kristine Stenzel and Leo Wetzels for their valuable suggestions for the carrying on of this study. I also want to thank Lyle Campbell and Keren Rice for their comments and suggestions on some drafts of this study. Of course, I take responsibility for any mistake still remaining. Fieldwork was partially funded by the Endangered Language Funds, Department of Linguistics at the U of Utah and the Steffensen Cannon Scholarship.

the acoustic study, describing the data collection and the methods of instrumental analysis. In Section 4, I report the results of this study, first highlighting the general patterns, then detailing differences in timing in oral versus nasal contexts. Section 5 presents the discussion and implication of the results, presenting the changes that take place in oral versus nasal contexts and comparing these results with the primary work that was the model for the present study. Finally, Section 6 is an appendix of the words and measurements used in this study.

2. The question and some background information: nasal harmony in Desano

The aim of this paper is to report on an acoustic study of intervocalic voiceless stops in oral versus nasal contexts in DES. This study investigates Kaye's statement that "it is unclear whether the voiceless segments … have distinct oral and nasal realizations" (Kaye 1971: 37). This study follows an analysis by Walker (1998) of Guaraní. As in DES, the voiceless stops in Guaraní are "transparent" to nasal harmony, i.e. while the voiced segments are affected by nasality, the voiceless segments are not; they act transparently. Walker provides an acoustic comparison of oral and nasal word pairs in Guaraní and analyses the effects that nasal harmony has on transparent voiceless stop. She presents several findings regarding context-dependent differences in voice onset time, closure of the stop, and closure duration in oral versus nasal environments. She shows that "voiceless stops surface as oral stops in nasal spreading domains" in Guaraní (Walker 1998: 226). Another finding in Guaraní, which I intend to test for DES, is that the total period of voicelessness seems to be fixed independent of context, i.e., the total period of voicelessness is preserved in its total duration but is shifted in relation to stop closure and release in nasal environments. I follow Walker's methods of analysis for Guaraní in order to investigate whether her findings and generalizations hold for another language with nasal harmony.

We now provide an overview of nasal harmony in DES. Detailed descriptions of nasal harmony in DES have been provided in Kaye (1970, 1971), and a small report on the nasalization process in DES is presented in Miller (1999). However, no instrumental phonetic study of DES has been undertaken. Studies of nasal harmony in ET languages have been of

theoretical interest, for example, with respect to issues such as transparency of voiceless segments, nasal spreading and blocking across morphemes, and the interaction of nasality with the metrical structure.[2] The focus of the present study is the transparency of voiceless segments in nasal harmony. As background for this phonetic study, I outline the main characteristics of nasal harmony in DES following the descriptions in Kaye (1971). The DES phonemic inventory for consonants and vowels is given in Table 1 (after Miller 1999: 9).

Table 1.

	LABIAL	CORONAL	VELAR	GLOTTAL
PLOSIVE				
[-voiced]	**p**	**t**	**k**	**(ʔ)**
[+voiced]	**b**	**d**	**g**	
FRICATIVE		**s**		**h**
FLAP		**r**		
APPROXIMANT	**w**	**y**		

Desano Consonant Phonemes

	FRONT	MID	BACK
HIGH	**i**	**ɨ**	**u**
MID	**e**		**o**
LOW		**a**	

Desano Vowel Phonemes

DES has twelve consonants and six vowels. All vowels have phonemic nasal counterparts and the voiced consonants have nasal allophones. Voiceless segments [**p, t, k**] do not have nasal allophones and behave transparently in nasal environments. The voiceless fricative [**h**] has a nasal allophone [**h̃**]. All the consonants can occur as onsets. Also, [**d**] and [**r**] (flap) are in complementary distribution: [**d**] occurs in word-initial position and [**r**] word-internally. There may be some question concerning

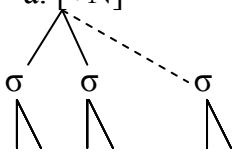
[2] Besides DES, there are descriptions of nasal harmony available for other ET languages: Tuyuca (Barnes 1996); Barasana (Gómez-Imbert 1997, 1998); Tukano (Ramirez 1997), and Wanano (Stenzel 2004, 2007).

the status of glottal stop [ʔ] and therefore I have put it in parentheses.[3] DES basic syllable structure is (C)V. The glottal stop is the only consonantal segment that appears in a coda position giving the sequence CVʔ in the language. Bisyllabic lexical roots usually have are (C)VCV.

The description of nasal harmony outlined here does not pretend to be exhaustive; instead, I point out some basic characteristics of the phenomena in order to put the present study in context. (For more information on nasal harmony on DES, see Kaye (1970, 1971) and Miller (1999). For detailed analysis of the nasal harmony in other ET languages, see works listed in Footnote 2.

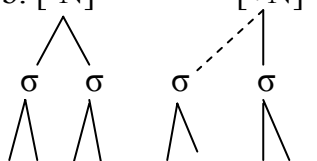
Nasal harmony in DES is a suprasegmental feature of the morpheme. Morphemes are inherently marked as oral [-nasal], nasal [+nasal] or are unmarked for nasality [Ønasal]. The unmarked morpheme receives the [±nasal] feature from the morpheme to its left (progressive assimilation) or to its right (regressive assimilation) through spreading. The examples in (1) illustrate nasal harmony in DES with cases of both progressive (1a) and regressive (1b) assimilation (data from Kaye 1971: 38-39).

(1) a. [+N]



s e d a + d u
pinaple-CLS:round
[**sẽnãnũ**] pinaple

b. [-N] [+N]



b a ʔ a + d i + d a
because (we) ate
[**baʔanĩnã**]

For more details on nasal harmony in DES and how the rules of spreading apply see (Kaye 1970, 1971). In the next section I describe the set up for present study and the data that is used.

[3] In a recent study of the phonological status of the glottal stops in the ET languages (Wanano, Piratapuya, Tukano, Desano and Siriano), Stenzel (2007: 334) suggests that "while such stops do occur, they are not themselves phonemic segments, but rather the surface realization of phonemic, suprasegmental glottalization, whose distinguishing feature is [constricted glottis]."

3. Set-up

3.1. Data and data collection

This study focuses on the phonetic characteristics of intervocalic stops in oral versus nasal contexts. (Voiceless fricatives are not considered here; due to their continuancy, they require different methods of analysis.) The data of this study consist of 25 words in which the medial consonants were the voiceless stops [**p**], [**t**] and [**k**], which formed the subject of this investigation. From these words, fifteen oral/nasal pairs were compared in the three places of articulation: five for [**p**], four for [**t**] and six for [**k**]. Since I do not have data in which oral/nasal pairs differ only in terms of the place of articulation of the stop, I selected the data with a view to the intervocalic position of the stops in oral versus nasal contexts. Some examples are given in (2). A complete list of the words used in this study is given in Section 5.

(2) Examples of words with voiceless stops in intervocalic position.

	Oral		**Nasal**	
	VCV		ṼCṼ	
a.	[**bupʉ**]	thunder	[**ũpĩkõ**]	breast milk
b.	[**uti**]	wasp	[**ũtã**]	stone
c.	[**gaki**]	monkey	[**ĩmĩkã**]	smoke

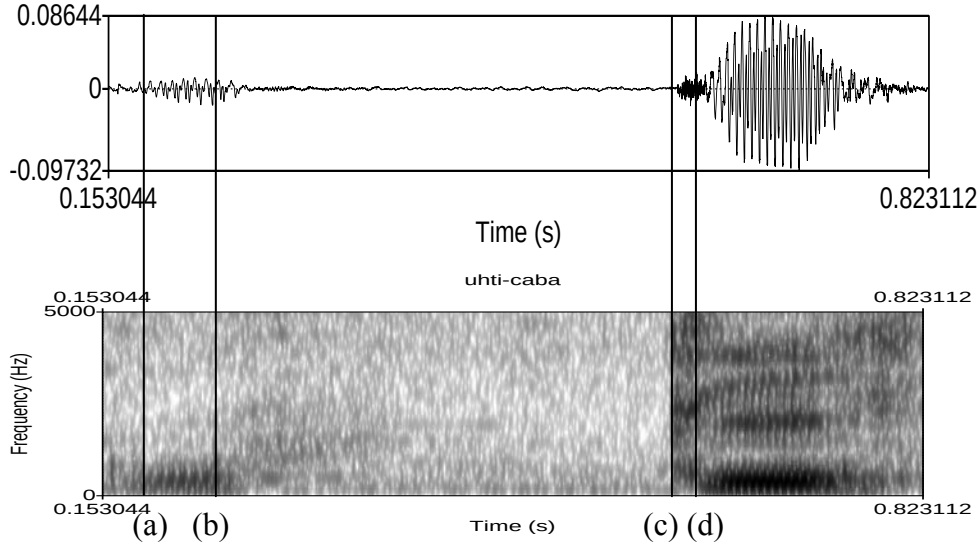
The language consultant for this study was a Desano male, 68 years of age, who also speaks Tukano (his mother's language) and Portuguese. The consultant has native fluency in Desano and Tukano. He lives in the municipality of São Gabriel da Cachoeira, in the Northwest Amazonia Region. He left his home community when he was in his mid forties. Nowadays, the languages he speaks at home are Portuguese and Tukano. The consultant uses DES only with relatives and/or friends who speak the language fluently. The wordlist was not designed with this particular study in mind. It was elicited with the consultant based on pictures and real physical material available. Thus, the consultant did not read any wordlist. When a picture or an object for a given word was not available, the consultant would just translate from Portuguese to DES.

The recordings were made in a small room at the consultant's house. External noise was constant. Words were elicited at a normal speech rate. The consultant repeated each word at least three times. Only one token was measured, as some tokens were elicited too carefully and did not represent a normal speech rate.

3.2. Instrumental analysis

The recordings were made with an EDIROL digital recorder using a sampling rate of 16Hz, WAV format. Measurements of durations of the segment components were taken using PRAAT Software, making reference to both waveforms and spectrograms. On each spectrogram for each word, four points were tagged. The criteria by which those points were identified are described below, and they are illustrated in (3) showing the VCV segment of the oral word [**uti**] 'wasp'.

(3) Sample waveform and spectrogram for VCV form [**uti**] 'wasp'.



a. Initiation of closure for medial voiceless stop.
b. End of voicing into medial stop.
c. Release of stop closure.
d. Onset of voicing in following vowel.

Various durations were measured based on the four marked points of each token. In using these measurements points, I follow Walker's

(1998) acoustic study of Guaraní voiceless stops. As in Walker's study, this report focuses on five durations: (i) Closure Voicing: measuring from the initiation of stop closure (3a) to the end of voicing after the first vowel (3b); (ii) Closure Duration: measuring from the initiation of closure (3a) to the release of closure (3c); (iii) Voiceless Closure Duration: measuring from the point of end of voicing into the stop (3b) to the release of closure (3c); Voice Onset Time: measure from the release of the stop closure (3c) to the onset voicing (3d); (v) Total Voiceless Period: measurement of the duration from the end of voicing into the stop (3b) to the onset of voicing in the following vowel (3d). These five durations (i-v) were measured for each of the oral and nasal words and then averaged and compared for the analysis. The measurement numbers and statistical analysis (average and standard deviation) were performed using Excel 11.0 software. In the following section, I report the interpretation of the results.

4. Results

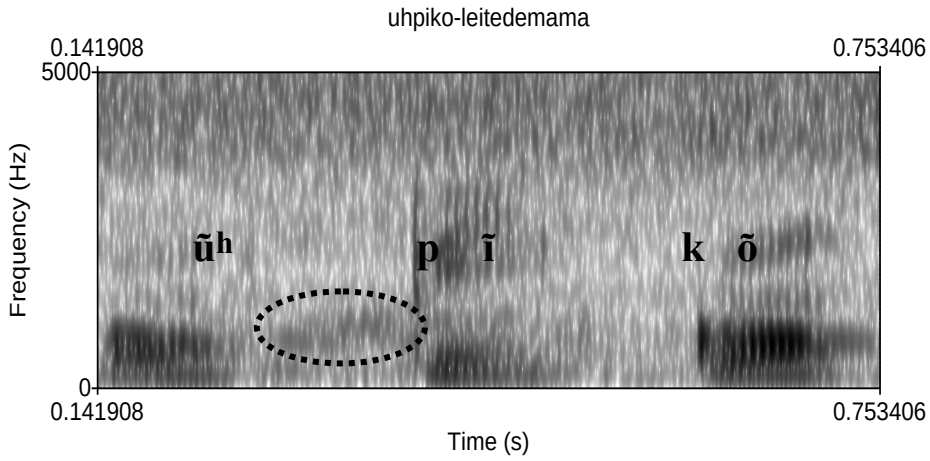
The results are similar to the patterns found by Walker (1998) for Guaraní. Although there are some important findings in DES which are different from the patterns found in Guaraní. The results are discussed below.

4.1. General patterns

First, I point out the general patterns of voiceless stops in both oral and nasal contexts. The voiceless segments /**p, t, k**/ are realized as oral in both oral and nasal contexts. However, in nasal contexts, although they do not become fully voiced or fully nasal during the closure, nor are they fully produced as voiceless nasal stops; the segments /**p**/ and /**t**/ show consistent visible differences in both their waveforms and spectrograms when compared to their position in oral environments. In these two segments, a nasal leak, i.e. a weak energy characteristic of nasal flow, is visible in the closure period of the voiceless stops /**p**/ and /**t**/ in nasal environments. This is not consistently seen with /**k**/. I assume that /**k**/ behaves differently from /**p**/ and /**t**/ because of its articulatory properties. I hypothesize that since /**k**/ is produced further back on the velar ridge, the velum is unlikely to be lowered. The lack of voicing during the stop is clearly visible from both the spectrogram and the waveform of all segments. A sample waveform and spectrogram for the nasal word [**ũpĩkõ**] 'breast milk' is shown in (4).

Note that the closure period of /**p**/ shows visible energy, whereas the closure period of /**k**/ does not.

(4) Sample spectrogram for [**ũpīkõ**] 'breast milk'.



This acoustic information shows that the voiceless stops /**p**/ and /**t**/ are phonetically affected by nasality and do not seem to behave totally transparently; they seem to be instances of 'false transparency', in which the velum remains lowered through the full duration of a segment. This analysis differs from the 'cursory' observation made by Walker (1998: 243, footnote) of some audio recordings of DES,[4] which led her to claim that DES voiceless stops are non-nasal on the surface.

I discuss below the details of the differences in the timing of the various durations measured for the voiceless stops in oral and nasal contexts, and discuss the differences that are conditioned by nasal environments. For the effects that might be conditioned by nasal contexts, I follow the analysis proposed by Walker (1998: 243) and offer a defining acoustic property of voiceless stops in DES.

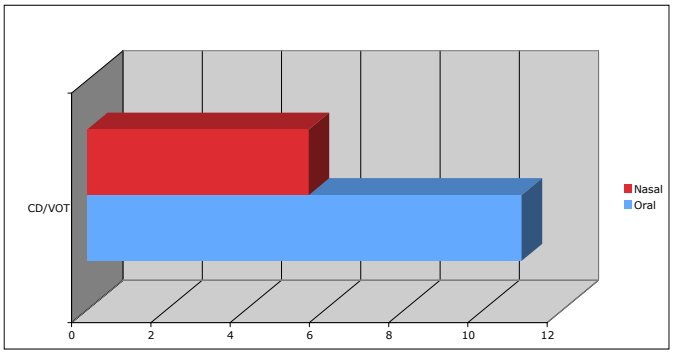
4.2. Effect 1: Ratio of closure duration to voice onset time

Walker (1998: 243) found that, in Guaraní, the average ratio of closure duration to voice onset time (CD/VOT) is shorter in nasal contexts than in oral ones. The same pattern is found for the voiceless stops in DES. The CD/VOT ratio was calculated together in order to control for any word/token variation in speaking rate. The differences in the ratios of closure duration over voice onset time are given in (5), based on all three

[4] Walker used analog audio recordings of Desano (of Colombia) made by Jonathan Kaye 1965-1966.

places of articulation. The average for oral contexts of 10.968 is greater than the average for nasal contexts of 5.594, a significant difference.

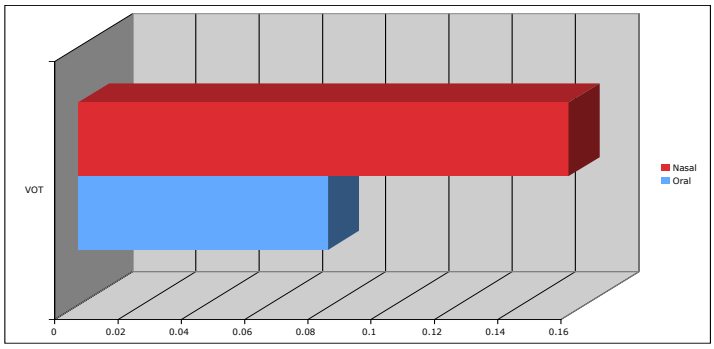
(5) Closure duration/Voice onset time (CD/VOT): results across sample



	Oral	>	**Nasal**
Number of tokens	15		15
Variance	17.023		0.734
Avarage CD/VOT	**10.968**	>	**5.594**

Walker (1998:244) attributes the difference in the ratio of closure to voice onset time to the fact that in nasal contexts voice onset times are longer and closure durations are shorter. The average voice onset times are given in (6): 0.079 msec. in oral words and 0.155 msec. in nasal words.

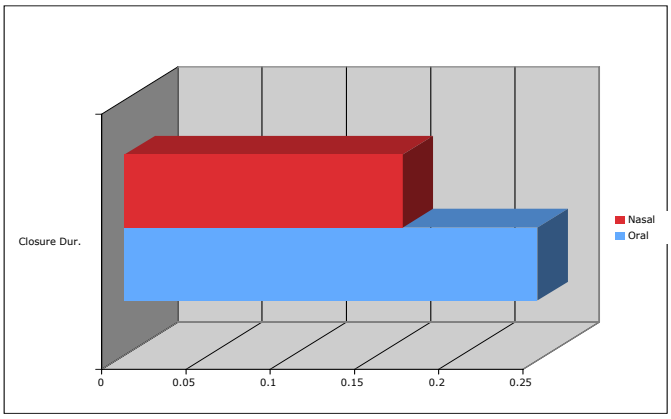
(6) Greater VOT in nasal contexts.



	Oral	>	**Nasal**
Number of tokens	15		15
Variance	3.088		1.530
Avg VOT (msec.)	**0.079**	>	**0.155**

Average closure durations for the intervocalic voiceless stops are shown in (7). The average closure is longer in oral environments (0.245 msec.) than in nasal environments (0.165 msec.).

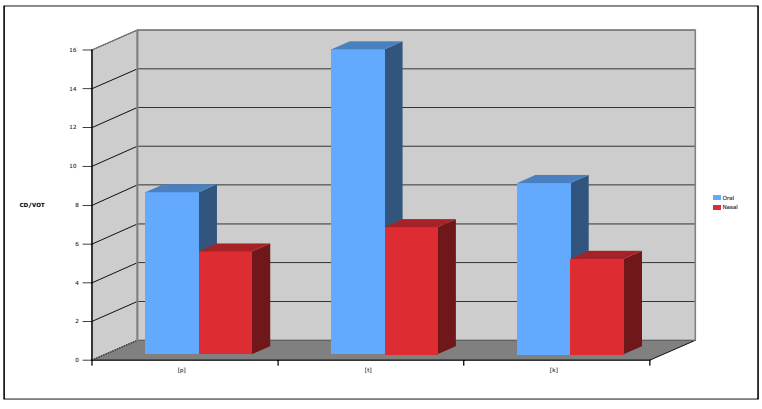
(7) Shorter closure durations in nasal contexts.



	Oral >	**Nasal**
Number of tokens	15	15
Variance	0.005	0.002
Avg. closure dur. (msec.)	**0.245**	**0.165**

The results reported above represent the entire sample of data. When we look at the tokens sorted by place of articulation, we notice that all the places interact significantly with the difference in CD/VOT in nasal versus oral stops. The results for closure duration over onset time for each place of articulation are displayed in (8). For all segments, the ratio is significantly greater in oral contexts than in nasal ones. For [**t**] the difference is greatest, with an average of 15.724 for oral words and an average of 6.559 for oral words. The figures for [**p**] and [**k**] are roughly similar: for [**p**] the average of 8.353 in oral contexts versus nasal average of 5.303; and [**k**] has an average of 8.826 for oral contexts versus the nasal average of 4.921.

(8) Closure duration/Voice onset time by place of articulation.

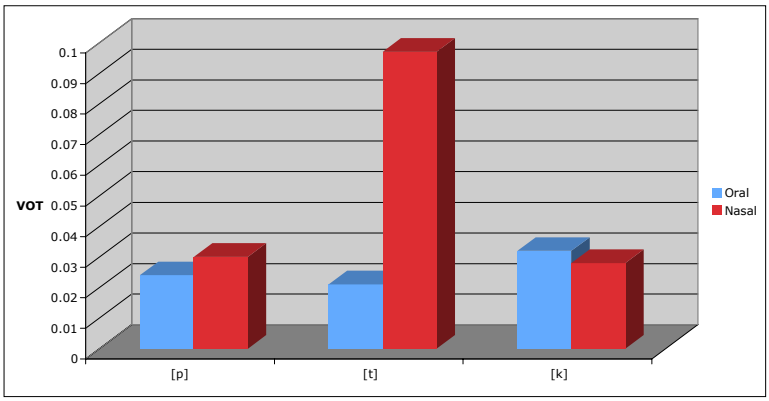


Oral Nasal

	[**p**]		[**t**]		[**k**]	
	Oral > Nasal		**Oral > Nasal**		**Oral > Nasal**	
Number of tokens	5	5	4	4	6	6
Variance	12.053	4.192	40.629	15.184	12.301	4.243
Avg. CD/VOT	**8.353 > 5.303**		**15.724 > 6.559**		**8.826 > 4.921**	

(9) gives voice onset time by place of articulation. When sampled individually by place of articulation, we notice that only [**p**] and [**t**] exhibit greater voice onset times in nasal contexts, with [**t**] showing a particularly greater difference of nasal versus oral context (oral average of 0.024 msec. for [**p**] and 0.021 for [**t**] versus nasal average of 0.030 for [**p**] and 0.097 for [**t**]. [**k**] shows a different pattern in which there is no significant difference in voice onset times in oral versus nasal words (oral average of 0.032 msec. versus nasal average of 0.028 msec.); its voice onset time is consistently about 0.030. The same pattern was found for the voice onset time in Guaraní: VOT for [**k**] does not show a significant difference (Walker 1998: 247).

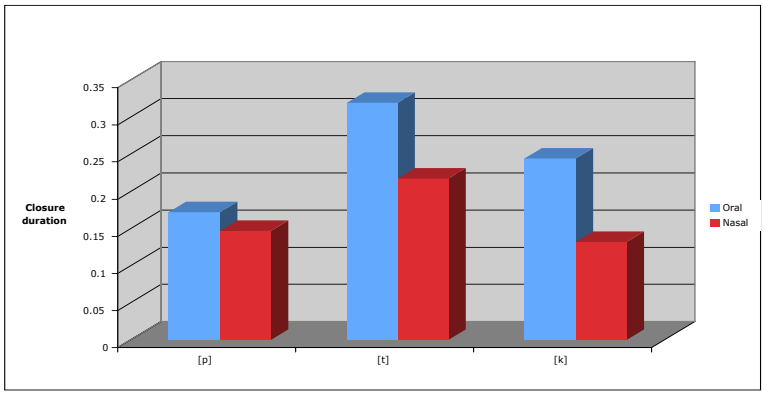
(9) Voice onset time by place of articulation.



Oral ■ Nasal ■	[**p**]		[**t**]		[**k**]	
	Oral > Nasal		**Oral > Nasal**		**Oral < Nasal**	
Number of tokens	5	5	4	4	6	6
Variance	0.0001	0.000	0.000	0.0223	0.0002	2.856
Avg. VOT (msec.)	**0.024**	**0.030**	**0.021**	**0.097**	**0.032**	**0.028**

The values for closure duration by place of articulation are shown in (10). Here, [**p**] presents a slightly different pattern from the [**t**] and [**k**] with a short closure on oral contexts when compared with its nasal counterpart (oral average for [**p**] 0.172 msec. versus nasal average 0.147). On the other hand, the closure duration for [**t**] and [**k**] is significantly shorter in nasal contexts when compared with oral contexts (oral average for [**t**] 0.319 msec. and for [**k**] 0.244 msec. versus nasal average for [**t**] 0.217 msec. and for [**k**] 0.132 msec.

(10) Closure duration by place of articulation.



Oral ■ Nasal ■	[p]		[t]		[k]	
	Oral < Nasal		**Oral > Nasal**		**Oral < Nasal**	
Number of tokens	5	5	4	4	6	6
Variance	0.001	0.001	0.012	0.008	0.005	0.002
Avg. closure dur. (msec.)	**0.172**	**0.147**	**0.319**	**0.217**	**0.244**	**0.132**

In sum, the findings reported so far show that the ratio of closure duration to voice onset time is greater in oral contexts than in nasal ones. The contributing factors for this pattern are that voice onset time is longer in nasal words and closure durations are shorter in nasal words. This pattern is also reported for Guaraní. Walker points out that

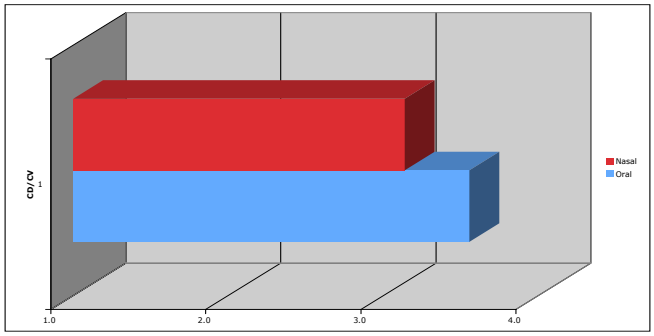
> "the greater values in nasal words give a great denominator in CD/VOT, yielding smaller ratios for nasal environments' and that 'the shorter closures in nasal words give a greater numerator in the CD/VOT ratio, contributing to the smaller nasal CD/VOT values" (Walker 1998: 243).

The general pattern that has been identified for the DES voiceless stops in nasal intervocalic environments is similar to the general pattern identified for Guaraní: voiceless stops have longer voice onset times and shorter closures.

4.3. Effect 2: Ratio of closure duration to closure voicing duration

The second effect analyzed in the production of voiceless stops in oral versus nasal words is the average ratio of closure duration to closure voicing duration (CD/CV). It was found that in DES, the average of the CD/VC ratio is significantly smaller in nasal words. This means that a significant portion of the closure is voiced in nasal vocalic environment. The averages are given in (11), taken across all three places of articulation. The oral average of 3.554 is significantly greater than the nasal average of 3.137.

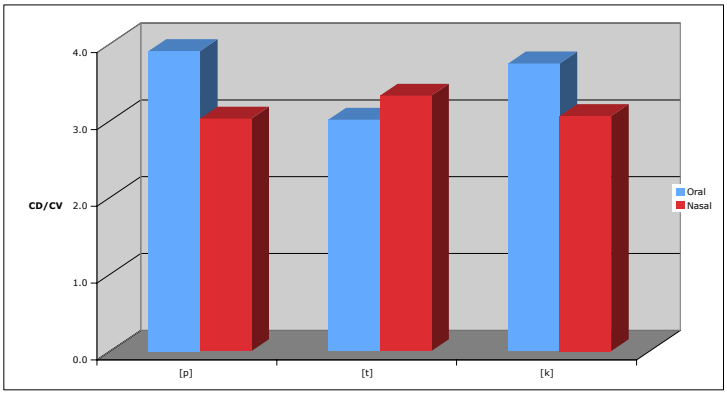
(11) Closure duration/Closure voicing duration (CD/CV): result across sample.



	Oral	>	**Nasal**
Number of tokens	15		15
Variance	4.223		0.767
Avg. CD/CV. (msec.)	**3.554**		**3.137**

In (12), I present the average of closure duration to closure voicing by place of articulation. [**t**] differs from [**p**] and [**k**] in that the ratio for [**t**] is greater in nasal context (3.324 msec.) versus the oral one (3.013 msec.). The ratio for [**t**] does not appear to be significant. For [**p**] and [**k**] durations are shorter in nasal words (oral average 3.905 msec. for [**p**] and 3.743 for [**k**] versus nasal average 3.027).

(12) Closure duration/Closure voicing duration (CD/CV) by place of articulation.



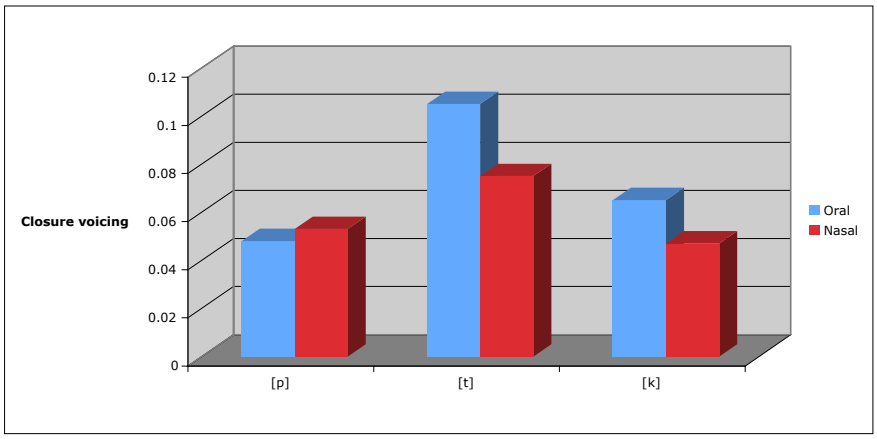
Oral Nasal

	[p]		**[t]**		**[k]**	
	Oral > Nasal		**Oral > Nasal**		**Oral > Nasal**	
Number of tokens	5	5	4	4	6	6
Variance	4.011	1.495	0.149	2.891	0.864	1.277
Avg. CD/CV	**3.905**	**3.027**	**3.013**	**3.324**	**3.743**	**3.060**

The ratio for closure voicing is presented in (13). [**p**] presents a different pattern from [**t**] and [**k**], in which its closure voicing in nasal context (0.048 msec.) is a little bit greater than its closure voicing in oral contexts (0.053 msec.). Despite the difference from the other segments, the

closure voicing of [**p**] does not have significant differences in the nasal versus oral context. For [**t**], closure voicing is greater in oral context (0.105 msec.) versus the nasal context (0.075 msec.). Like [**t**], the closure voicing for [**k**] is greater in oral context (0.065 msec.) versus (0.047 msec.) in nasal contexts. The pattern found here for [**t**] differs from the one reported for Guaraní. In Guaraní, [**t**] shows a greater closure voicing in nasal contexts (Walker 1998: 253).

(13) Greater closure voicing for [**t**] in oral contexts.

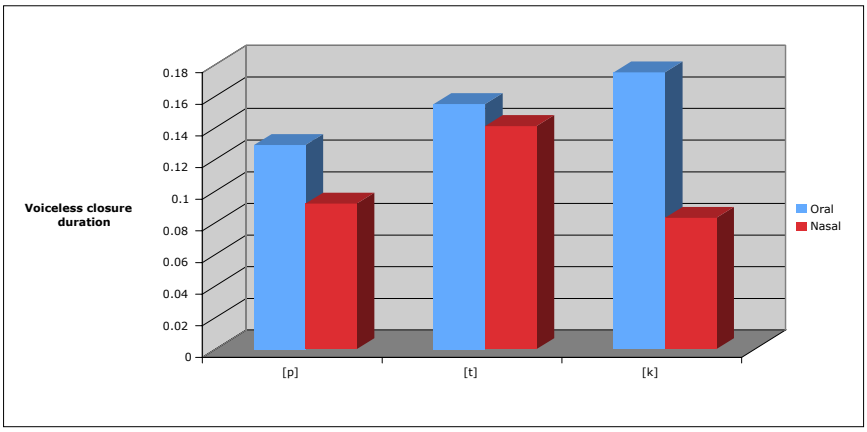


Oral ■ Nasal ■

	[**p**]		[**t**]		[**k**]	
	Oral > Nasal		**Oral > Nasal**		**Oral > Nasal**	
Number of tokens	5	5	4	4	6	6
Variance	0.000	0.000	0.000	0.001	0.000	0.000
Avg. closure voicing (msec.)	**0.048**	**0.053**	**0.105**	**0.075**	**0.065**	**0.047**

One last property that was reported for all places of articulation in Guaraní, which was also attested to occur in DES, is a shorter duration of the voiceless period of the closure in nasal contexts. However, while Guaraní holds a consistent duration across the places of articulation; in DES these durations vary across the different places of articulation. This is illustrated in (14). [**p**] and [**k**] are significantly different with short voiceless closures in nasal contexts (oral average for [**p**] 0.129 msec. and for [**k**] 0.175 msec. versus nasal average for [**p**] 0.092 msec. and for [**k**] 0.083 msec. Voiceless closure duration for [**t**] is not significantly shorter in nasal words, as we can see in (13).

(14) Voiceless closure shorter in nasal contexts in all places of articulation.

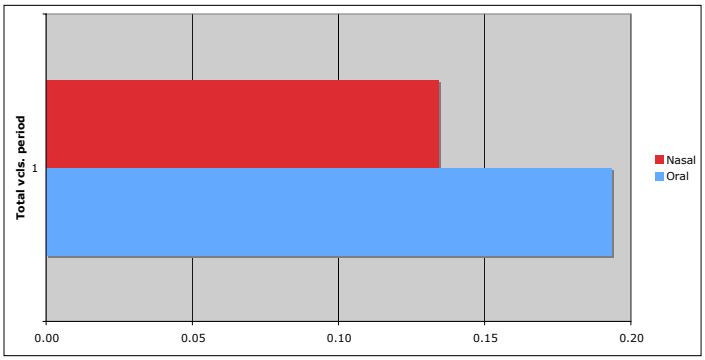


Oral ■ Nasal ■	[p]		[t]		[k]	
	Oral > Nasal		**Oral > Nasal**		**Oral > Nasal**	
Number of tokens	5	5	4	4	6	6
Variance	0.002	0.001	0.005	0.006	0.004	0.001
Avg. voiceless closure (msec.)	**0.124**	**0.093**	**0.197**	**0.141**	**0.179**	**0.083**

4.4. Total period of voicelessness: not a fixed property

The last finding to be reported here is regarding the total period of voiceless for the stops in oral and nasal contexts. In Guaraní, it was found that the stops [**p, t, k**] have a fixed property of voicelessness in oral and nasal contexts, i.e., across the data, the total period of voicelessness for these stops does not hold a significant difference in oral versus nasal words (Walker 1998: 254). The findings I report here for DES are different: voicelessness is not a fixed property in this language; it differs significantly in oral versus nasal words. The averages are given in (15).

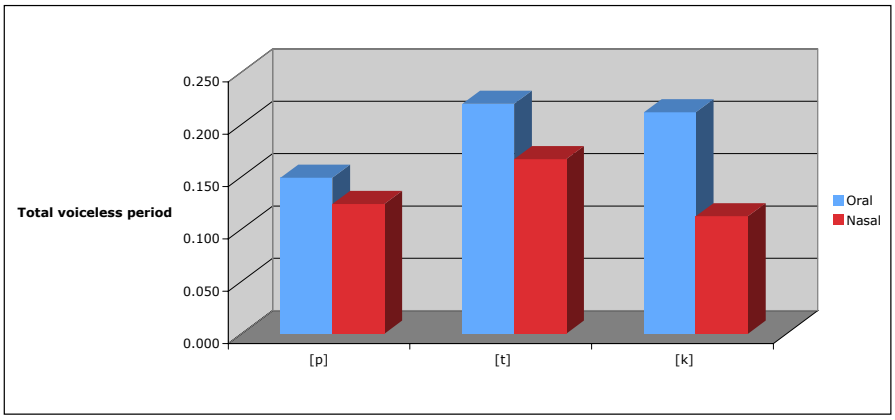
(15) Total period of voicelessness is different for nasal and oral words: results across samples.



	Oral ■	>	**Nasal ■**
Number of tokens	15		15
Variance	0.001		0.000
Avg. vcls. dur. (msec.)	**0.193**		**0.134**

This difference is more noticeable when we compare the averages for the total period of voiceless for place of articulation. However, one would want to single out [**p**] in contrast to [**t**] and [**k**], because of its shorter contrast in oral versus nasal context. This is illustrated in (16). Nevertheless, [**t**] and [**k**] conform to the statement in (15) with a significant difference in their total voiceless period in oral versus nasal contexts.

(16) Total period of voicelessness by place of articulation.



Oral ■ Nasal ■	[**p**]		[**t**]		[**k**]	
	Oral > Nasal		**Oral > Nasal**		**Oral > Nasal**	
Number of tokens	5	5	4	4	6	6
Variance	0.002	0.001	0.006	0.007	0.004	0.001
Avg. voiceless duration (msec.)	**0.149**	**0.124**	**0.220**	**0.167**	**0.212**	**0.112**

In sum, we have noticed that the total period of voicelessness is significantly different in oral versus nasal contexts. This finding differs from the one for Guaraní, in which the voicelessness period is characterized as having a fixed property, with no difference in the total period of voicelessness in nasal/oral contexts.

5. Conclusions and implications

This study has been modeled after Walker's (1998) study of Guaraní voiceless stops in oral versus nasal contexts.[5] The results reported for DES in this study show that, in these contexts, the voiceless stops in DES show some similarities with the same segments of Guaraní.

[5] See Chapter 4: A phonetic study of Guaraní, in Walker (1998).

An important finding of this study is that the voiceless stops [**p**] and [**t**] do not act completely transparently to nasal harmony. In nasal contexts, the spectrograms for those two segments show that there is some energy produced by nasal flow, in the closure period of these voiceless stops. This is not found for [**k**], which fact I explain as being due to the articulatory property of [**k**], during the production of which the velum is completely closed. Although there is a nasal flow in the closure duration of [**p**] and [**t**], these segments remain voiceless. Thus, at least phonetically these segments seem to be affected by nasality, although their basic non-sonorant voiceless articulation remains intact.

So far, the results of this study present some implications for the theoretical claims about how to analyze nasal harmony in DES. The differences detected between the voiceless segments [**p, t**] (the status of [**k**] needs further study) in nasal versus oral environments warrant treating these segments as though they undergo nasal harmony; however, this nasality is not shown in terms of 'true nasality' on the surface, even though it is present phonetically. Maybe, for nasalised segments to be defined as transparent phonologically, nasality must be audible (or perceptible). Our results also raises some new directions for future research. In DES, voiceless stops [**p, t**] in nasal words seem to be (slightly) different allophones of the oral voiceless stops [**p, t**]; although they remain voiceless, they are nevertheless affected by nasality.

This study showed that, in nasal environments, voice onset time is longer and closure duration is shorter. This also appears to happen in Guaraní. Another phenomenon that also occurs in Guaraní is the ratio of closure duration to closure voicing duration, which is significantly smaller in nasal words. On the other hand, DES differs from Guaraní in that, in the latter language, the total period of voicelessness is a 'fixed property', while in the former it shows a significant variance. In order to verify whether the results of this study represent general characteristics of the language, a larger set of data must be analyzed. Further analysis of the findings in this report is currently being undertaken (Silva *forthcoming*).

6. Appendix: DES words used for this study

	Oral		Nasal	
1.	[**etoka**]	cubiu (fruit)	[**ũtã**]	stone
2.	[**dipuru**]	head	[**ĩmĩkã**]	smoke
3.	[**bupʉ**]	thunder	[**ũpĩkõ**]	breast milk
4.	[**uti**]	wasp	[**ŋãkʉ̃**]	talo do cacho da banana
5.	[**gaki**]	monkey	[**ĩmĩkã**]	smoke
6.	[**duka**]	forearm	[**kẽkãriri**]	suvaqueira (odor da axila)
7.	[**gapitogʉ**]	vaga-lumes	[**mõh̃õtõ**]	arm (biceps)
8.	[**kuipoari**]	eye brows	[**mõmẽtore**]	colméia (dentro de um tronco)
9.	[**yapoa**]	face	[**nẽpõrãrũ**]	buritizeiro
10.	[**yukʉ**]	tree	[**ʉ̃tãmũ**]	cachoeirinha
11.	[**gapi**]	bush (used to prepare drink)	[**waiyupõrã**]	cheeks
12.	[**diaposero**]	forehead	[**hopõrãrũ**]	broto da bananeira

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