ACOUSTIC DESCRIPTION OF SPANISH NASAL CONSONANTS IN CONTINUOUS SPEECH

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The aim of this paper is to compare some acoustic cues of the Spanish nasal consonants in two different speaking styles: Continuous speech versus laboratory speech.
The items analized in continuous speech have been obtained from an hour recording of speech produced by a male native Spanish speaker. In order to obtain the items in laboratory speech, the same subject was instructed to read the set of analized utterances in citation form. Broadband spectrograms were made with a MacSpeech Lab II programme to analyse the consonant duration and nasal formant frequencies. The results suggest that between the analyzed speaking styles, differences in duration are more important than in formant frequencies.

INTRODUCTION

There is an agreement among phoneticians on the relevance of the following features that characterize the nasals as a class (Delattre[1]; Fant[2]; Fujimura [3]): a low first formant at about 300Hz, with higher intensity than the upper formants, the existence of the antiformant and a set formants which have a lower intensity level than those of neighbouring vowels. Furthermore, Fant (1960) states than there is a relationship between nasal and vowel formants. There is a correspondence of N1 to F1, N3 to F2, and in some instances N4 to F3. This correspondence is a matter of continuity since a formant may be equally dependent on the nasal oral cavities.
Fujimura (1962) distiguishes between variable and invariant formants.
According to this author there are some formants that remain relatively unaffected by the context: *The second formant of the [n], for example, is located always around 1000 cps. for all samples of [n]* (p.246).
In our work, we have taken into account the consonant duration and nasal formant frequencies.

PROCEDURE

We used for this experiment an hour recording of speech produced by a male native speaker of Spanish. Natural continuous speech was obtained by asking questions about the subject's work, military service, his village and his family.
"Laboratory speech" refers to utterances read in citation form by a speaker.
In order to obtain the items in laboratory speech, the same subject was instructed to read the set of utterances that appear in continuous speech corpus as naturally as possible at a normal speech rate. The order of these utterances was randomized. The recordings were made in a sound proof room at the phonetics laboratory at the Autonomous University of Barcelona, using a Revox A/77 tape recorder and a Shure 515 Sb Unidyne microphone.
Formant frequencies were made of nasal consonant in intervocalic context. In some of the cases, the vowel that followed the consonant was stressed and in other cases it was unstressed. The number of items was eight hundred and thirty: three hundred and seventy samples of which correspond to the first context and four hundred and sixty to the second one.Table I shows the number of analyzed cases for each consonant.

Tablel: Number of analyzed cases for Spanish nasal consonants in both contexts.

	VCV́	V́CV
[m]	199	142
[n]	153	249
[ɲ]	24	70

The recorded speech material was digitised at 10 KHz and analysed by means of spectrograms using a MacSpeech Lab II programme. In the selected sequences the duration and the formant frequencies were measured.

RESULTS

The data obtained from the acoustical analysis were subjected to a statistical treatment. The mean values of the given parameters (X) as well as the standard deviation (sd) are shown in the following tables. Table II correspond to laboratory speech values of nasal formants in the context VCV́ and V́CV in laboratory speech and Table III shows the same values in continuous speech.

Table II: Nasal formant values in laboratory speech when the nasal consonant is followed by a stressed or by an unstressed vowel.

VCV́	X	sd	V́CV	X	sd
[m]	351	33	[m]	348	28
	1071	74		1070	43
	1038	282		783	116
	2194	68		2239	69
[n]	361	29	[n]	370	21
	1032	45		1039	28
	1606	172		1599	183
	2318	51		2323	51
[ɲ]	375	24	[n]	375	20
	1062	29		1064	30
	2001	134		2076	141

Table III: Nasal formant values in continuous speech when a nasal consonant is followed by a stressed or by an unstressed vowel.

VCV́	X	sd	V́CV	X	sd
[m]	400	66	[m]	414	64
	1060	99		1022	70
	1309	151		1118	417
	2123	96		2177	90
[n]	427	64	[n]	430	54
	1002	66		1042	54
	1562	167		1500	192
	2261	90		2287	77
[ɲ]	468	44	[ɲ]	433	44
	1048	28		1048	40
	1943	130		2009	126
	2334	28		2455	67

If we compare these results, it can be observed that the first formant frequencies in continuous speech are higher than in laboratory speech. In the second formant frequencies there are no significatnt differences in both speaking styles. In the third formant , the frequencies are higher in laboratory speech, except to the consonant [m]. It can be noted that in laboratory speech N3 of the consonant [m] has values below N2. This finding is due to the influence of the vowels.
The fourth formant frequencies have similar results for [m] and [n]

consonants, if we compare both speaking styles.Nevertheless, in laboratory speech, this formant is impossible to be distinguished in the palatal consonant.
On the other hand, standard deviation values of the N3 (Tables II and III) show an important dispersion in our data.For this reason, the results of the third nasal formant have been separated depending on vowel contexts. Tables IV and V show these results in continuous speech (CS)and in laboratory speech (LS) taking into account the vowel stress.

Table IV: Values of N3 when the consonant is followed by an unstressed vowel ("pal" and "vel" are palatal and velar contexts and the stress means that the preceding vowel to the consonant is stressed).

V́CV	CS	LS
pál [m] vel	1378	834
pál [m] a	1651	—
pál [m] pal	1253	1275
vél [m] pal	1348	1203
vél [m] a	—	797
vél [m] vel	735	727
á [m] vel	—	749
á [m] a	—	—
á [m] pal	—	—
pál [n] vel	1565	1643
pál [n] a	1616	1695
pál [n] pal	1740	1712
vél [n] pal	1431	1485
vél [n] a	1231	1269
vél [n] vel	—	—
á [n] vel	1299	1340
á [n] a	1290	1388
á [n] pal	1475	1477
pál [ɲ] vel	1981	2192
pál [ɲ] a	2162	2242
pál [ɲ] pal	—	—
vél [ɲ] pal	—	—
vél [ɲ] a	1998	2212
vél [ɲ] vel	—	—
á [ɲ] vel	1943	2044
á [ɲ] a	2003	2111
á [ɲ] pal	—	—

It can be observed in table IV that laboratory speech results are lower than continuous speech ones for the consonant [m], but in the other nasal consonants they are similar. In some contexts, there are not any data because the number of cases is insufficient for a statistic treatment.

Table V: Values of N3 when the consonant is followed by a stressed vowel ("pal" and "vel" are palatal and velar contexts and the stress means that the following vowel to the consonant is stressed).

VCV́	CS	LS
pal [m] vél	—	—
pal [m] á	—	—
pal [m] pál	1339	1271
vel [m] pál	—	916
vel [m] á	—	776
vel [m] vél	—	700
a [m] vél	—	745
a [m] á	—	—
a [m] pál	—	1246
pal [n] vél	1697	1722
pal [n] á	1464	1599
pal [n] pál	1630	1705
vel [n] pál	1327	1436
vel [n] á	—	—
vel [n] vél	—	1222
a [n] vél	1357	1261
a [n] á	1419	1359
a [n] pál	1469	1497
pal [ɲ] vél	2088	2061
pal [ɲ] á	2094	2118
pal [ɲ] pál	—	1985
vel [ɲ] pál	—	—
vel [ɲ] á	—	—
vel [ɲ] vél	—	—
a [ɲ] vél	—	—
a [ɲ] á	1917	2000
a [ɲ] pál	1926	2013

In table V, the continuous speech results are usually lower than the results in laboratory speech.

On the other hand, very different results are shown in both tables if we compare velar and palatal context. N3 goes down in velar context and it goes up in palatal one.

The duration results are shown in table VI. We have separated the cases depending on the vowel stress and the speaking style.

Tabla VI: Duration of nasal consonants according to vowel context.

Context	LS	SD	CS	SD
V́ [m] V	92	16	55	16
V́ [n] V	64	12	41	11
V́ [ɲ] V	98	13	64	16
V [m] V́	66	11	61	13
V [n] V́	48	9	37	12
V [ɲ] V́	69	12	59	11

It can be noted in table VI that the duration is much smaller in continuous speech. But when the consonant is followed by an unstressed vowel the duration difference between both styles is greater (47 ms for [m], 23 for [n] and 38 for [ɲ]). In these cases, it ican be observed that [ɲ] > [m] >[n] in all samples.
Nevertheless, when the nasal consonant is followed by a stressed vowel [m] >[ɲ]>[n] in continuous speech and [ɲ]>[m]>[n] in laboratory speech.

CONCLUSIONS

The results presented in the tables above show the relevance of the duration when we compare continuous speech versus laboratory speech. The difference is more significant if we take into account the vowel stress.
The frequency results show differences in the first formant: in continuous speech it is higher than in laboratory speech. But we don't observe important differences in N2, N3 and N4. Only , the third formant frequency in [m] consonant goes down in laboratory speech with relation to continuous speech results.
On the other hand, in both styles, the frequency of N1, N2 and N4 formants is relatively constant while the N3 frequency varies considerably with the context, having a high frequency before the vowels [i] and [e] and a low frequency before the vowels [o] and [u].
This fact could be explained following Fant's assumptions about the dependence between formants and cavities:N3 could be dependent on the oral cavities.
Future research would be necessary in order to decide if this dependence on the oral and nasal cavitiy is related to the speaker.

REFERENCES

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