

SPECTROGRAPHIC STUDY OF THE VOWELS
[a] and [ɐ] IN PORTUGUESE

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1. Introduction

1.1. Vocalic system

Lusitanian Portuguese¹ is said to have the following vocalic system. Nasal vowels have been traditionally considered to be phonemic, i. e. distinct from the corresponding oral vowels.

(1)	$ \begin{array}{c} i \quad (\text{ə}) \quad u \\ e \quad \quad \quad o \\ \text{ɛ}(\text{ɐ})\text{ɔ} \\ \quad \quad \quad a \end{array} $	$ \begin{array}{c} \tilde{i} \quad \quad \quad \tilde{u} \\ \tilde{e} \quad \quad \quad \tilde{o} \\ \tilde{\text{ɛ}} \end{array} $
	(a) oral	(b) nasal

The vowels in (1) are all those which appear at the surface level and some of those which appear only at this level. For example, [ɐ] manifests itself perhaps most frequently as an unstressed variant of the underlying /a/. Alternations such as shown in (2) support this view:

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- (2) falar "to speak" [fɛlar] /falar/
falo "I speak" [fálu] /falu/
fala "(he) speaks" [fálɐ] /fala/
falado "spoken" [fɛladu] /faladu/

When an /a/ is followed by a nasal consonant, then the stressed [ɛ] emerges. This process is also accompanied by the nasalization of the vowel. Examples are:

- (3) cama "bed" [kɛ̃mɐ]
cana "cane" [kɛ̃nɐ]
sanha "rage" [sɛ̃ɲɐ]

If we adopt the following binary distinctive feature system², these examples can be easily explained by a rule.³ The fact that the nasal vowel system provides exclusively [-low] vowels seems to support this rule.

	i e ɛ ɐ a ɔ o u ə ⁺	
high	+ - - - + +	V → [+nasal] / — N
low	- + + + -	
back	- - - + + + + +	Nasalization rule with the effect
round	- - + + + -	of vowel closing

Although the rule seemingly works well, the distinctive feature system is not phonetically well motivated and has certain inherent problems. This implies, of course, that the rule should be reconsidered. For example, Redenbarger (1975) has pointed out that the [ɐ] is not a back vowel, and is in fact a front vowel. But so far as we operate only with the features [high, low, back and round], the possibility of assigning the feature [-back] to the vowel [ɐ] is excluded.

1.2. Consonant system

The consonant system of Portuguese is shown below:

p	b (β)			m	w
		f	v		
t	d (ð)	s	z	ʎ	ɲ
		ʎ		ɲ	j
k	g (ɣ)	(ɸ)		(ɲ)	

(Consonants in parentheses appear always as allophones. All others have phonemic status, at least in a certain environment.)

The /r/ and /c/ make contrast in the same way as they do in Spanish. /b/, /d/ and /g/ are said to be spirantized in intervocalic position, but this does not occur so frequently as is the case in Spanish. Distinctions among /s/-/z/-/ʃ/-/ʒ/ are effective except for the syllable final-position, in which either [s], [z], [ʃ] or [ʒ] occurs, depending on the environment.

2. The Nature of the Opposition between /a/ and /ɐ/

2.1. The problem

Within the framework of classical phonemics, one of the most controversial problems in the vocalic system of Portuguese is no doubt that concerning the theoretical status of the phoneme /ɐ/. We have seen, however, that in most cases an [ɐ] that appears at the surface level can be derived from an underlying /a/. In fact, however, there are examples that show the opposition between /a/ and /ɐ/, and in a "taxonomic" sense, we must admit the existence of the phoneme /ɐ/. In other words, there is no better way in classical phonemics to express this opposition than by setting up the phoneme. In the generative framework, on the other hand, we are much better equipped with means that enable us to express such a surface contrast without necessarily differentiating the underlying forms. In classical phonemics, on the contrary, setting up of the phoneme is obligatory in our case, but once this is done, there arise a certain number of problems that otherwise need not be taken into consideration. The aim of this section is to show how troublesome it is to set up the phoneme /ɐ/.

2.2. The phoneme /ɐ/

If we follow the argumentation made by J. M. Barbosa (1965), manifestations of the phoneme /ɐ/ have three different sources: (1) between -amos and -ámos (see next section) there is a contrast of the vowel quality, and -amos contains /ɐ/ which is distinct from /a/ in -ámos; (2) proclitics and enclitics show the phoneme /ɐ/ when emphasized or in some substantive usages; and (3) in the diphthong [ɐi] the first part of it shows /ɐ/.

In the following section we will discuss only the first case in some detail, since the surface contrast between -amos and -ámos seems to constitute the strongest support of the argument in favor of the phoneme /ɐ/.

2.3. -amos and -ámos

Two inflectional forms of the verb falar "to speak" are shown in (1). The former is the 1st person plural present indicative form and the latter is the 1st person plural preterit. Both take on penultimate stress: the acute accent of the latter is an orthographical convention to distinguish these two forms: The stressed vowel of the former shows [ɐ], while that of the latter appears as [a], although both are followed by one and the same nasal consonant /m/. As has been shown in the preceding chapter, Portuguese has a very general rule that converts /a/ followed by any nasal consonant into [ɐ], and therefore the [a] before /m/ of the latter form is quite extraordinary in this language. Nevertheless, these two forms are distinguished by the difference in the phonetic qualities of [ɐ] and [a].

(1)		phonetic representations	(taxonomic) phonemic representations
	<u>falamos</u> "we speak"	[fɛlɛmuʃ]	/falɛmuS/
	<u>falámos</u> "we spoke"	[fɛlámuʃ]	/falámuS/

It should be noticed here that the above-mentioned example is in no way an isolated exception. Indeed, there are hundreds of such minimal pairs because all regular verbs terminating in -ar in the infinitive show this type of alteration. And since, furthermore, the number of such verbs is greatest of the three regular conjugation verbs (i. e. those ending in -ar, -er and -ir in the infinitive), one might conclude that the opposition /a/-/ɛ/ has considerable "rendement fonctionnel," and hence the phoneme /ɛ/ exists. Such may be the views of the Prague phonologists. J. M. Barbosa, for example, states as follows:

On constate même que la fréquence de /ɛ/ est, dans -amos, très élevée, aussi bien dans le lexique que dans le discours, puisque cette terminaison apparaît dans tous les verbs portugais, "réguliers" et "irréguliers" (à la 4^e personne du présent de l'indicatif des verbs en -ar, du présent du subjonctif des verbs en -er et en -ir). Etant donné d'autre part que les verbs en -ar sont les plus nombreux des verbs portugais, on voit jusqu'à quel point l'opposition /ɛ/-/á/ est vivante et efficace dans la conjugaison verbale (J. M. Barbosa, 1965, pp. 59-60. His /α/⁵ is replaced by /ɛ/).

Apparently, here, the author somewhat overestimates the role of the opposition /ɛ/-/a/. This opposition is attested among the so-called 1st conjugation types (i. e. those ending in -ar in the infinitive), but not among any other conjugation types, including "irregular" verbs. In fact, we have such forms as shown in (2):

(2)	<u>comamos</u>	(< <u>comer</u> "to eat")	present subjunctive
	<u>partamos</u>	(< <u>partir</u> "to leave")	"
	<u>estamos</u>	(< <u>estar</u> "to be")	present indicative

but their counterparts are lacking. In other words, while the forms in (2) contain the phoneme /ɛ/ (according to Barbosa's view), there are no such forms that are identical with these forms except that they contain /a/ before /m/ instead of /ɛ/. Thus the function of the opposition /ɛ/-/a/ is in reality limited to the 1st conjugation verbs. One thing has become clear through the quotation above: Barbosa considers the stressed [ɛ] before /m/ always to be the realization of the phoneme /ɛ/.

The above-discussed state of affairs reminds us of Halle's famous example from Russian (I avoid quotation and illustration here because this has been done again and again in the literature). Let us consider the forms in (3):

(3)		phonetic representations	taxonomic phonemic	systematic phonemic
	<u>cama</u> "bed"	[kɐmɐ]	/kɐmɐ/	/kama/
	<u>cana</u> "cane"	[kɐnɐ]	/kɐnɐ/	/kana/
	<u>sanha</u> "rage"	[sɐɲɐ]	/sɐɲɐ/	/sɒna/

Each noun in (3) contains in the first syllable an /a/ which is subject to the nasalization rule and subsequently becomes [ɐ] (I avoid noting ~ to show nasalization, since only vowel height is relevant here). Post-Bloomfieldian phonologists would represent these forms by making use of the phoneme /ɐ/ since the opposition /a/-/ɐ/ is present in this language (shown in (3) as "taxonomic phonemic"). Against this, generative phonologists would claim that the [ɐ] could be derived from an underlying /a/ and therefore there is no need to posit /ɐ/ in the underlying representation (shown in (3) as "systematic phonemic").

However, against Halle's example from Russian, Fischer-Jørgensen (1975) has claimed that his argument is valid only for post-Bloomfieldian phonemics and "Troubetzkoy would have a /T/ (with no specification for voicing)." And indeed, in our case, Barbosa operates with archiphoneme; in Portuguese the opposition /a/-/ɐ/ exists before /m/ but not before any other nasal consonants and, therefore, his archiphonemic representation would be something like this:

(4)		archiphonemic representations
	<u>cama</u>	/kɐma/
	<u>cana</u>	/kɐna/
	<u>sanha</u>	/sɐpa/

Representations in (3) obscure the generality of the nasalization rule. But a more serious problem of Barbosa's analysis lies elsewhere. Now it's time to go back to our first example.

(1)		phonetic representations	Barbosa's phonemic interpretation
A	<u>falamos</u>	[fɐləmuʃ]	/falɐmuS/
B	<u>falámos</u>	[fɐlamuʃ]	/falamuS/

In form A, the [ɐ] is followed by /m/ and therefore its particular phonetic quality is due to the nasalization rule. It seems most natural to assume that it could be derived from an underlying /a/. As far as form A is concerned, there can be nothing that prevents us from supposing so. Nonetheless, Barbosa had to posit here the phoneme /ɐ/ for the sake of the opposition. But what makes the opposition possible? What makes it possible is apparently the extraordinariness of the [a] before /m/. In short, in spite

of all this, he has to assign the most common /a/ to the extraordinary form B, and, on the contrary, the troublesome /ɐ/ must be assigned to the most common form A. The argument is not only counter-intuitive, but also fails to express the generality of the nasalization rule as well as the extraordinariness of the [a] before /m/.

Recently, however, M. H. M. Mateus (1973) has made an attempt to answer this question in her generative treatment of the phonology of Portuguese, in which both [ɐ] in -amos and [a] in -âmos have an identical underlying representation /a/ and where they are differentiated in the process of derivation.⁶ But her approach is highly abstract as is often the case with recent generative studies, and, in my opinion, more careful observations of the phenomena at the phonetic level are necessary before making any abstract analysis. That is one of the reasons why I undertook the spectrographic study described in the next section.

3. An Experimental Study on the Phonetic Qualities of [a] and [ɐ]: How they differ acoustically

3.1. Purpose

This section is devoted to the description of an experiment whose purpose is to examine the phonetic qualities of [a] and [ɐ] in acoustic terms. Before going further, let us briefly summarize the contexts in which principal allophones of /a/ appear.

word level

In unstressed position ----- [ɐ]: (generally speaking)
 In stressed position ----- [ɐ]: before nasal consonant
 ----- [a]: otherwise

But the stressed [a] is not completely excluded from the position followed by /m/. As we have seen in the preceding section, preterits of the 1st conjugation verbs exceptionally show [a] in this environment.

sentence level

The above argument is valid only for tonic words; atonic words, such as proclitics and enclitics, do not behave like these. In normal speech, they always show [ɐ], even if emphasized or substantively used (see pp. 156)

At word level, the phonetic quality of /a/ is controlled by two independent parameters, i. e. stress and the presence of a nasal consonant that immediately follows /a/. Therefore the first thing we should do is to compare the phonetic qualities of the stressed /a/ and its unstressed counterpart, as well as the /a/ followed by a nasal consonant and /a/ not followed by one.

The next step is the comparison between -amos and -âmos. The point at issue in this case is how it becomes possible to produce [a] before /m/.

Finally, at sentence level, a comparison between proclitics of normal use and their substantively used counterparts will be made in the present experiment. But, for the following reason, this step does not carry so

much weight as do the previous two steps. Chomsky and Halle (1968) claimed that in English stress contours have at least four "perceptual" levels, and this may perhaps hold true in the case of Portuguese, as suggested by J. M. Câmara (1972) and M. H. M. Mateus (1973). And yet no experimental study has ever succeeded in demonstrating this "fact" in acoustic terms (cf. Lehiste (1970), p. 150). It is also obvious that the investigation of the stress contours at sentence level requires much more preparation than are needed at word level. Consequently, our third-step experiment concerns only a limited aspect of the phenomena at sentence level.

3.2. Method

3.2.1. Acoustic parameters

In the present experiment, formant frequency and duration have been chosen as acoustic parameters, the former representing phonetic quality and the latter degree of stressedness.

Following the common practice of the past few decades, the lowest three formant frequencies have been measured and the first two will be used in setting up an F1-F2 diagram, which has been agreed to represent the phonetic quality of the vowel.

As to the acoustic measurement of the "stressedness," it is generally known that "there is no one-to-one correspondence between stress and any single acoustic parameter" (quotation from Lehiste (1970), p. 110). In Portuguese, however, increase in duration seems to represent "stressedness" most effectively. This assumption is based upon my own observation as well as statements found in the literature. For that matter, the following remark by Barbosa is relevant here:

... Certes, la mise en relief d'une syllabe au moyen d'une plus forte énergie n'est pas exclue, mais il ne faut pas oublier que cette plus forte énergie se traduit généralement, non pas nécessairement par un sommet dans la courbe générale des intensités, mais par un allongement de la syllabe comportant l'accent: il se peut, par exemple, que dans un enregistrement d'un mot comme casa "maison", la syllabe accentuée ca n'apparaisse pas comme ayant une intensité plus grande que celle de la syllabe -sa, mais comme étant plus longue que celle-ci (J. M. Barbosa (1965), pp. 213-214).

3.2.2. Speech materials

Corresponding to the three steps mentioned above in 3.1, speech materials used in this experiment consist of three kinds. They are shown in Table 3.1.

The list shown in Table 3.1 contains some apparently archaic or dialectal forms, and we can find such forms only in a very voluminous dictionary such as António De Moraes Silva's "Grande Dicionário Da Língua Portuguesa." And yet the list contains no nonsense words. Some irregularities found in Part I are due to this principle (irregularities here refer to the forms that deviate from the formula given at the head of Part I, and they are in parentheses).

Table 3.1. Speech materials. In Part I's formula given in diagonals, C₁² stands for one or two consonants.

	Part I	[r]	cara - (carata)	[ʒ]	caga - cagada
C ₁ ²	/káC ₁ ² a/-/kaC ₁ ² áda/	[r]	carra - carrada	[ʒʒ]	canga - cangada
[p]	capa - capada	[rt]	carta - cartada	Part II [-k _f muʃ] - [-kámuʃ] picamos - picámos bicamos - bicámos ficamos - ficámos riscamos - riscámos pecamos - pecámos secamos - secámos vacamos - vacámos sacamos - sacámos mascamos - mascámos marcamos - marcámos tocamos - tocámos chocamos - chocámos brocamos - brocámos buscamos - buscámos	
[b]	caba - cabada	[rd]	carda - cardada		
[br]	cabra - cabrada	[rn]	carna - carnada		
[m]	cama - camada	[l]	cala - calada		
[mp]	campa - campada	[ld]	calda - caldada		
[mb]	camba - cambada	[ts]	calça - calçada		
[f]	cafa - (cafar)	[k]	calca - calcada		
[v]	cava - cavada	[ʃ]	catcha - cachada		
[t]	cata - catada	[ʃt]	casta - (castanha)		
[d]	cada - (cadaste)	[ʃk]	casca - cascada		
[s]	caça - caçada	[j]	caia - caiada	Part III "dois de cada" "dois de cada um" "dois para cada" "dois para cada um"	
[z]	casa - casada	[ʎ]	calha - calhada		
[n]	cana - canada	[ɲ]	canha - canhada		
[nt]	canta - cantada	[k]	caca - cacada		
[nd]	canda - (candado)				
/Ns/	cansa - cansada				

Throughout the list, the /a/ in question is always preceded by /k/; thus its phonetic quality is a function of the following segment as well as of the stress. This environmental conditioning is essential in the experiment that compares the phonetic quality of /a/ followed by a nasal consonant with that of /a/ not followed by one. And this conditioning also makes it possible to compare the results of Part I with those of Parts II and III, at least to some extent. The reason for choosing /k/ as the fixed preceding segment is that the Portuguese lexicon seems to provide greater variety for the segment that comes next to /-a-/ when the syllable begins with /k/ than in any other cases. And the items in Part I reflect this variety: they cover almost all the consonants that can appear in intervocalic position. Only two are lacking, namely, /ʒ/ and /w/. And the lack is, again, due to the principle mentioned above.

Items in Part I are quasi-minimal pairs with regard to stress assignment. For example, in the pair capa-capada, both take on penultimate stress, and this causes the stressed first syllable /ká/ in capa and the unstressed first syllable /ka/ in capada. Thus our aim in this step is the comparison of the first syllables in both cases.

Items in Part II consist of true minimal pairs like picamos-picámos; in this example both are derived from the verb picar "to prick." Notice also that the phonological interpretation of the two kinds of /a/ is crucial in this step, and therefore the formulas given in Table 3.1 are in square brackets ([-k muʃ] - [-kámuʃ]).

Speech materials in Part III are all inspired by Barbosa (1965, pp. 68-69). He suggests that in phrases such as "dois de cada um" ("two of each one") and "dois para cada um" ("two for each one") where cada "each" is used proclitically, it does not take on stress and both syllables show [] (i. e. [k d]), whereas in "dois de cada" ("two of each") and "dois para cada" ("two for each"), cada is used substantively and takes on stress in the first syllable but it does not become [a]; instead, it shows [] (Barbosa posits here the phoneme / /, as has been shown in the last chapter).

Finally, all of the speech materials were pronounced in a frame sentence. For the items in Parts I and II, the following was used:

Esta palavra é _____ em português.

(This word is _____ in Portuguese.)

and

Esta frase é _____ em português.

(This phrase is _____ in Portuguese.)

was for the items in Part III.

3.2.3. Subject

The subject was a native speaker of Portuguese who speaks the Coimbra dialect. He teaches Portuguese at the University of Tokyo and several other universities in Tokyo.

The Coimbra dialect differs slightly from the Lisbon dialect upon which recent phonological studies are based (cf. Barbosa (1965), Mateus (1973)). But the most important thing is that both dialects distinguish -amos from -âmos. I asked our subject about this distinction and verified it. The following passages from G. Viana also attest to this:

... Devant la nasale m, l'a est partout fermé, à la seule exception de la terminaison -amos de la 1^{re} personne du pluriel du prétérit parfait de l'indicatif des verbs de la 1^{re} conjugaison (en -ar). L'a de cette terminaison se prononce ouvert à Lisbonne et Coimbre, et on fait une différence entre cette désinence et celle de la 1^{re} personne du pluriel du présent de l'indicatif des verbs en -ar, ... (G. Viana, 1941, p. 209)

It should also be noted that the subject found no difficulty in pronouncing all of the speech materials in a uniform fashion in spite of their non-uniformity, i. e. some are nouns, some are verbs, and some can be either a noun or a verb (e. g. caça can be a noun "hunting" or a verb "(he) hunts").

3.3. Experimental procedures

3.3.1. Arrangement of the speech materials

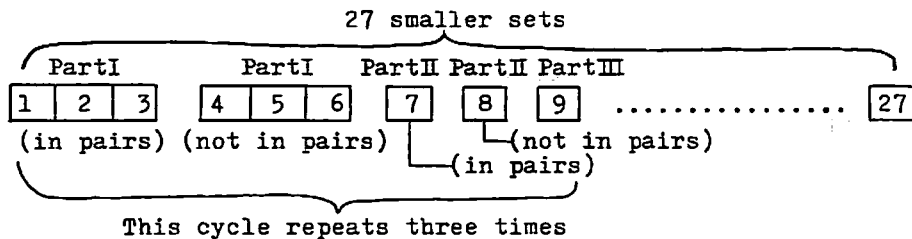
Speech materials were all pronounced in random order. For the items in Parts I and II two kinds of randomization were made. The first one keeps the pairs, such as capa-capada, ficamos-ficámos, etc., while the other one breaks them; in other words, in the former case the smallest unit in the randomization is a pair, while in the latter case a single item

is the smallest unit. And to keep a pair means here that the two items in a pair were pronounced successively one after another (but, of course, each was in the frame sentence).

Each item in Parts I and II was pronounced and recorded six times, three times in pairs and three times not in pairs. Each phrase in Part III was pronounced three times in random order.

In practice, the whole speech material, which contained six occurrences for each item in Parts I and II and three occurrences for each item in Part III, had become almost six times as large in size as the list shown in Table 3.1, divided into 27 smaller sets. Table 3.2 shows its construction.

Table 3.2. Speech materials construction in practice



These divisions were made so that the subject was able to take a rest at any time between the sets.

3.3.2. Recording

Recording was made in an anechoic chamber⁸ by using standard high-quality apparatus. The subject was asked to read the speech materials in a natural manner and with a constant speech rate. Speech materials were given in the form mentioned above. We prepared a metronome in order to maintain a constant speech rate, but it turned out that it was not so easy a task to adjust the subject's speech rate to the metronome's tempo. Therefore, each time after having taken a rest and just before going into the next session, the subject was asked to remember his rate by listening to the playback of the previous session.

3.3.3. Formant frequency measurement

A Kay Electric Company's Sona-graph was used to measure the formant frequencies.

Procedures of the measurement were as follows: first, a broad-band spectrogram was taken; then, after having decided the point to be measured, a narrow-band "section" was taken; next, the frequency-scale was enlarged by a factor of two, and the narrow-band section of the same point was taken again. The original frequency-scaled section was useful for "imagining" the spectrum envelope and for assuming the locations of the formants. The frequency-double-scaled section was useful for the measurements.

Difficulties residing in this method are of the same kind as discussed by Ladefoged (1967).

Generally speaking, formants were fairly easily detectable, owing to the subject's voice quality.

As to the point to be measured, the principle was to measure where steady state of the formant transition pattern can be seen, but this will be discussed in the following section in detail.

3.4. Results

3.4.1. Preliminary observations

Figure 3.1 shows spectrograms of the items cata and catada in Part I.

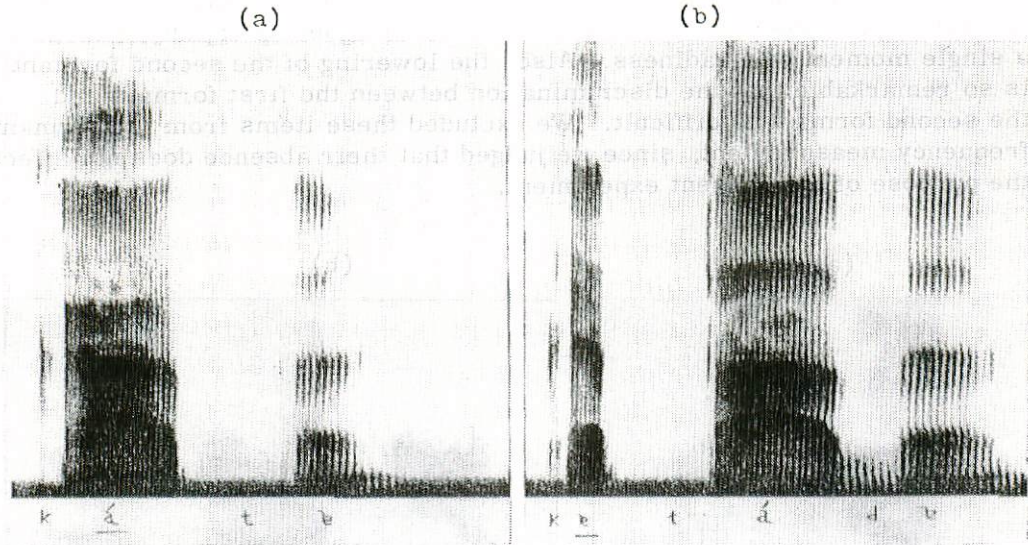


Fig. 3.1. Spectrograms of the items cata (a) and catada (b)

The /a/ in the first syllable of the former has a steady state of the formant transition patterns in the middle of the segment. Figure 3.2 schematizes this. As for the latter item, however, the /a/ in question shows no steady state. And the duration of the segment is significantly reduced; a comparison between the voiced parts shows that the latter /a/ is almost four times shorter than the former.

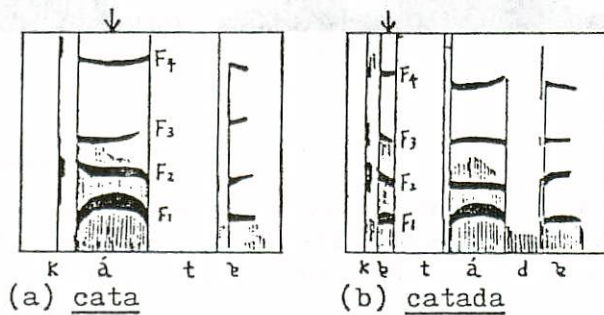


Fig. 3.2. Schematized formant transition patterns. Arrows indicate the points to be measured.

All other items follow this pattern: the stressed /a/ is always longer than its unstressed counterpart and shows steady state in the middle of the segment. Therefore it is quite natural to measure the formant frequencies at the center of the voiced part for the stressed /a/. But for the unstressed

/a/, there seems to be no better way than to make an ad hoc criterion. For comparison's sake we decided to measure at the center of the voiced part in this case too. Arrows in the Fig. 3.2 represent this.

As I mentioned, the examples above are the typical ones and almost all other items follow them, but there are some exceptions. The /a/ followed by /l/ exhibits no steady state even in the case of the stressed one. This is due to the "velarization" caused by /l/. Fig. 3.3 shows spectrograms of the pair calda-caldada, in which rapid movements of the formants can be seen. In both cases, as soon as the voicing begins, the second formant goes down and the third formant goes up rapidly without a single moment of steadiness. Also, the lowering of the second formant is so remarkable that the discrimination between the first formant and the second formant is difficult. We excluded these items from the formant frequency measurement, since we judged that their absence does not affect the purpose of the present experiment.

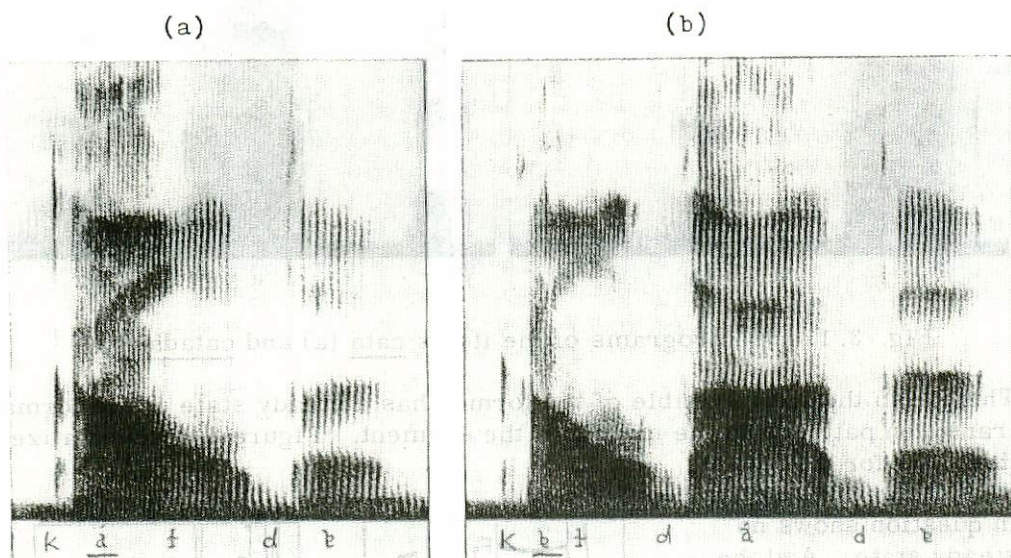


Fig. 3.3. Spectrograms of the pair calda (a) - caldada (b)

Fig. 3.4 contains spectrograms of the items campa and cama. The /a/ in campa has been traditionally considered to be a nasal vowel, but the presence of a nasal consonant [m] that follows /a/ is apparent. At any rate, one thing which is certain is that the /a/'s in both campa and cama exhibit considerable traces of nasalization; this can be seen by observing an abrupt change of the intensity distribution pattern at a certain point nearer to the beginning of voicing. From this point on, the intensity of the first formant becomes weaker until the end of the segment. It should also be noted that the first formant does not rise so high as is the case for the item cata (see Fig. 3.1). Nonetheless, the locations of the first and second formants are fairly clear and pose practically no difficulty in measuring them; the location of the third formant is quite obscure, however. As a matter of fact, the measurement of the third formant frequency was

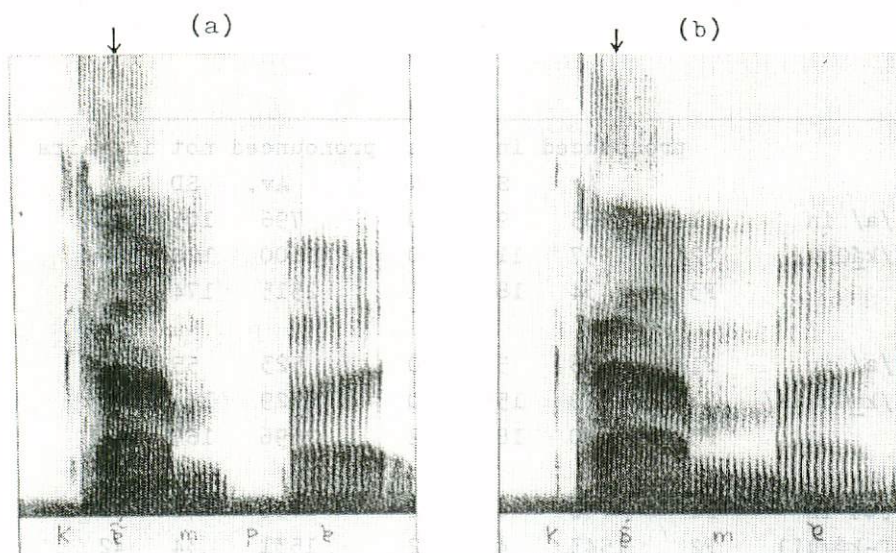


Fig. 3.4. Spectrograms of the items campa (a) and cama (b). Assumed onset of the nasalization is indicated by arrows.

often extremely difficult, and this was particularly the case when an /a/ is followed by an /m/. Therefore the measurement of the third formant frequency was excluded from the experimental procedure for the items in Part II, in which the /a/ in question is always followed by /m/.

3.4.2. Effect of the pair-pronunciation practice

As has been mentioned above in 3.3.1, items in Parts I and II were pronounced in two different manners. If "contrast effect" exists, the results may be affected. Generally speaking, however, our results of the two kinds of pronunciations show enough congruity to enable us to identify them.

Table 3.3 compares the results of the items pronounced in pairs with those of the items not pronounced in pairs. For the items in Part I (i. e. /káC²a/ and /kaC²áda/), congruity is remarkable except for the F3 values of the items that follow the formula /káC²a/. For the items in Part II, those that contain [ɐ] show good congruity, while F1 values of the items that contain [a] pose a question. But if we compare the values of formant frequencies between the items that contain [ɐ] and those that contain [a], the latter ones show greater F1 values than the former ones for both types of utterance, and the magnitudes of the differences between them are almost of the same order. Therefore, in the following discussion, we will identify these two kinds of utterances, and average formant frequencies over the total six utterances will be used as the representative of a single item (henceforth, acoustic measurements of the items in Part I, II and III will be referred to as Experiment I, II and III, respectively).

Table 3.3. Average formant frequencies of the two kinds of utterances. Each item was pronounced three times in pairs and three times not in pairs.

		pronounced in pairs			pronounced not in pairs		
		Av	SD	N	Av.	SD	N
/a/ in	F1	785	92	90	796	105	90
/káCᵀa/	F2	1597	112	90	1600	120	90
	F3	2434	185	71	2515	174	73
/a/ in	F1	526	55	90	523	55	90
/kaCᵀáda/	F2	1748	155	90	1729	154	90
	F3	2540	186	82	2596	187	86
[ɐ] in	F1	740	67	42	736	48	42
[-kámuf]	F2	1543	44	42	1531	34	42
[a] in	F1	856	71	42	822	66	42
[-kámuf]	F2	1536	56	42	1549	44	42

Av. = average formant frequency in Hz

SD = standard deviation

N = number of occurrences

3.4.3. Results of Experiment I

Table 3.4 presents the results of the formant frequency measurements of the items in Part I. Generally speaking, stressed /a/ has a greater F1 value and a smaller F2 value than its unstressed counterpart. As for the F3 values, the difference between them does not seem to be so distinct nor so systematic as are the cases of F1 and F2.

In Fig. 3.5 are plotted the F1 values against the F2 values for each item that appears in Table 3.4. Each datum point is represented by the consonant(s) following the vowel in question. A dotted line separates unstressed vowels from stressed ones; all of the unstressed vowels are located above the line, i. e. the F1 values of unstressed vowels do not rise more than about 620 Hz.

From Fig. 3.5, the following observations can be made:

- (1) Stressed vowels followed by any non-nasal consonant are located in a fairly small area; they can be said to have attained the vowel target of /a/.
- (2) Unstressed vowels, whether followed by a nasal consonant or not, take fairly definite F1 values, while in the case of the F2 values, their variation is rather great, and it is fairly easy to attribute their variation to the coarticulation

Table 3.4. Average formant frequencies in Hz. Each value represents an average of the six utterances.

	F ₁	F ₂	F ₃		F ₁	F ₂	F ₃
capa	878(45)	1548(33)	2428(77)	capada	495(37)	1677(148)	2440(73)
caba	807(54)	1533(34)	2470(144)	cabada	537(46)	1658(72)	2370(74)
cabra	775(91)	1518(27)	2492(261)	cabrada	500(22)	1545(100)	2448(85)
cama	772(60)	1628(38)	2470(80)	camada	495(32)	1623(79)	2472(157)
campa	673(34)	1700(66)	2582(78)	campada	495(49)	1693(77)	2480(202)
camba	760(38)	1683(53)	2735(35)	cambada	530(52)	1655(112)	2498(128)
cafa	820(61)	1523(22)	2518(116)	cafar	495(37)	1625(58)	2515(70)
cava	870(69)	1530(47)	2398(98)	cavada	528(23)	1605(46)	2423(39)
cata	803(54)	1550(49)	2390(89)	catada	505(26)	1772(60)	2677(147)
cada	773(85)	1553(46)	2563(167)	cadaste	532(33)	1642(38)	2693(147)
caça	902(124)	1543(61)	2508(63)	caçada	507(32)	1757(51)	2772(115)
casa	792(56)	1517(12)	2448(42)	casada	503(22)	1767(42)	2742(86)
cana	778(70)	1697(66)	2584(91)	canada	560(50)	1827(62)	2705(103)
canta	660(27)	1717(66)	2723(112)	cantada	547(37)	1748(72)	2773(112)
canda	657(29)	1717(69)	2590(179)	candado	562(62)	1798(35)	2687(148)
cansa	635(23)	1888(60)	2730(252)	cansada	532(74)	1875(73)	2742(127)
cara	838(44)	1555(24)	2525(108)	carata	615(24)	1618(73)	2492(90)
carra	798(64)	1490(47)	2440(64)	carrada	600(61)	1523(44)	2368(46)
carta	840(70)	1520(34)	2298(54)	cartada	537(41)	1625(59)	2362(106)
carda	793(69)	1508(13)	2236(62)	cardada	542(23)	1548(30)	2342(55)
carna	815(36)	1518(73)	2270(22)	carnada	545(26)	1560(77)	2323(55)
catcha	793(76)	1523(26)	2525(141)	cachada	482(45)	1838(30)	2672(56)
casta	877(134)	1490(50)	2237(63)	castanha	537(61)	1802(84)	2560(172)
casca	872(32)	1525(31)	2448(189)	casada	500(38)	1815(43)	2800(49)
caia	833(59)	1608(48)	2388(56)	caiada	525(48)	1945(73)	2533(72)
calha	870(50)	1543(26)	2245(95)	calhada	492(49)	1922(112)	2727(197)
canha	660(45)	1747(89)	2452(121)	canhada	463(43)	2052(64)	2744(164)
caca	842(40)	1568(44)	2312(126)	cacada	527(14)	1840(90)	2456(78)
caga	823(108)	1650(60)	2382(88)	cagada	477(52)	1848(137)	2462(35)
canga	700(72)	1855(60)	2668(111)	cangada	572(50)	1950(73)	2702(121)

effect. This can be verified by observing the locations of the vowels that have the same point of articulation: such vowels take almost identical F₂ values and are located close to each other.

- (3) Locations of the stressed vowels followed by nasal consonants are between the locations of the stressed vowels followed by non-nasal consonants and those of the unstressed vowels. The F₁ values are smaller than those of the stressed vowels followed by non-nasal consonants

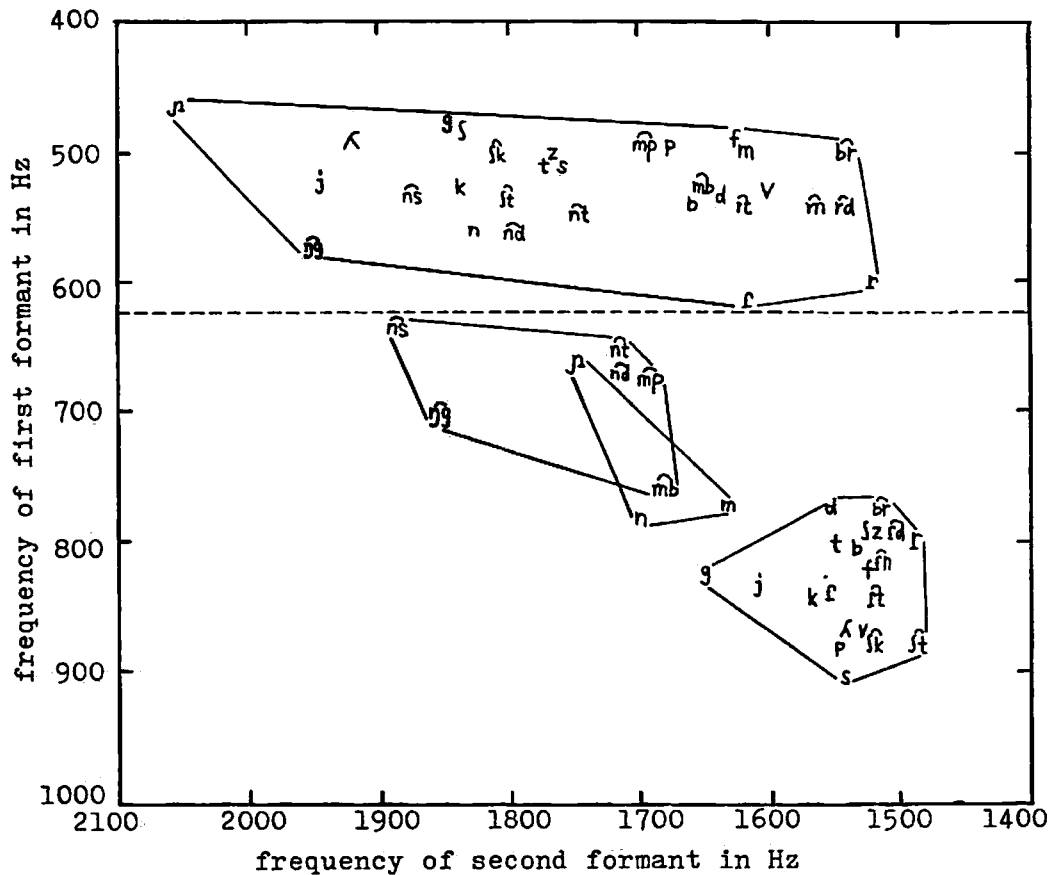


Fig. 3.5. F1-F2 vowel diagram. Each datum point is represented by the consonant(s) following the vowel in question. The dotted line separates unstressed vowels from stressed ones (below the line are the stressed vowels).

and greater than those of the unstressed vowels. Their deviation from the area of the normal stressed vowels may be due to the effect of the nasalization. In the cases of so-called nasal vowels, as in campa, canta, etc., their locations come slightly nearer to the area of the unstressed vowels than do the vowels in the forms such as cama, cana, etc. Perhaps the degree of nasalization is stronger in the former vowels than in the latter ones.

3.4.4. Results of Experiment II

Table 3.5 shows the results of the formant frequency and duration measurements of the items in Part II. Average formant frequencies over the total occurrences of [e] in -amos and those of [a] in -ámos are given at the bottom of Table 3.5. Both [e] and [a] have an almost identical F2

Table 3. 5. Average formant frequencies and durations of the items in Part II. Durations are given in milliseconds. Standard deviations are shown in parentheses.

	F1	F2	duration		F1	F2	duration
picamos	733(39)	1578(24)	154	picámos	880(66)	1570(48)	180
bicamos	728(61)	1548(51)	150	bicámos	897(70)	1575(28)	173
ficamos	755(45)	1587(15)	152	ficámos	848(63)	1558(25)	174
riscamos	755(45)	1518(21)	146	riscámos	847(67)	1520(30)	170
pecamos	717(49)	1555(32)	162	pecámos	822(65)	1548(7)	187
secamos	770(83)	1537(27)	151	secámos	832(73)	1540(28)	171
vacamos	748(47)	1543(27)	152	vacámos	840(57)	1580(31)	176
sacamos	763(52)	1563(18)	148	sacámos	818(46)	1573(45)	160
mascamos	773(47)	1527(22)	144	mascámos	838(47)	1525(26)	153
marcamos	713(35)	1547(25)	147	marcámos	813(83)	1605(72)	167
tocamos	718(76)	1522(49)	154	tocámos	807(47)	1503(49)	166
chocamos	742(67)	1488(16)	150	chocámos	837(97)	1500(31)	172
brocamos	727(55)	1497(22)	154	brocámos	852(62)	1487(29)	171
buscamos	710(38)	1512(23)	141	buscámos	820(63)	1512(31)	170
Av.	739	1537	150		840	1543	171

value, but the latter, i. e. [a] in -ámos, shows markedly greater F1 value.

The term "duration" means here what Lehiste and Peterson (1960) have called the "duration of the syllable nuclei," and thus includes the duration of aspiration. Hereafter we simply call it "duration of the vowel." As is shown in the table, duration of the vowel [e] in -amos is 150 ms and that of the vowel [a] in -ámos is 171 ms (average values); the latter duration is 14% longer than that of the former (see also Note 9).

Fig. 3. 7 shows the locations of [e] in -camos and those of [a] in -cámos. Locations of the items in Part I are also shown in the vowel diagram, for the purpose of comparison. The [a] in -cámos is located within the area of the stressed /a/ followed by non-nasal consonants. Thus, the traditional observation that the preterit form of the 1st conjugation verb shows [a] even before /m/ can be justified. However, although the [e] in -camos and [e] in cama are phonetically in the same environment, and thus we had expected that both would appear in an identical area on the vowel diagram, as shown in Fig. 3. 7, the F2 value of the former is about 100 Hz greater than that of the latter. We assumed this to be the influence of the segment that follows /m/. In the case of the item cama, an /a/ follows /m/, while in the case of the item, picamos, for example, what follows /m/ is an /u/ and possibly this /u/ has caused the difference in F2 value. Of course, we have no direct evidence that justifies this assumption, but there is a good reason to believe so. Let us take a look at Fig. 3. 8. It enlarges the areas in Fig. 3. 7 so that the location of each item can be seen; one surprising result seen in the figure is that a pair, for example, riscamos-riscámos, shows almost identical F2 values (this is indicated by vertical lines); and there is nothing that

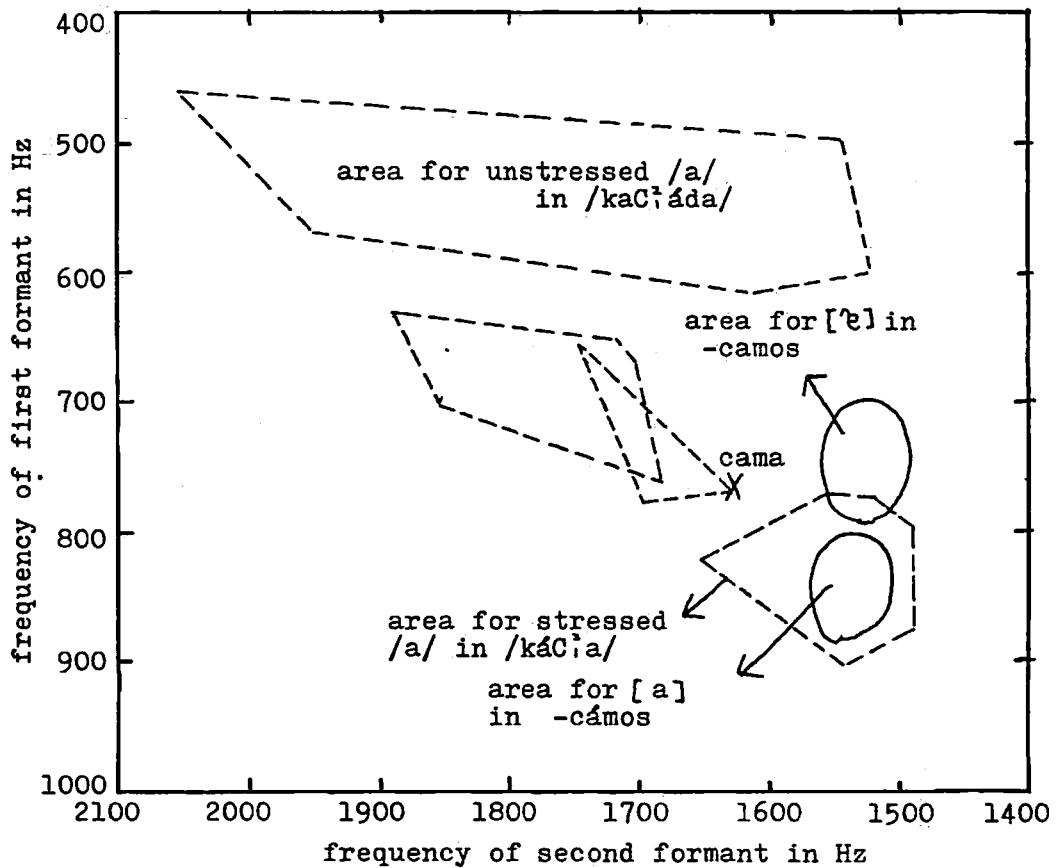


Fig. 3. 7. Locations of [e] in -camos and [a] in -cámos. X indicates the point of the item cama in Part I (see Fig. 3. 5)

can cause such a state other than the effect of the preceding segments. And since it is generally known that a segment is usually affected more by the following one than by the preceding one, the effect of the preceding segments in our case makes it possible to consider that the following /u/ may have an even greater influence upon /a/. Nonetheless, it is necessary to verify the above assumption by experimental study.

3. 4. 5. Results of Experiment III

Table 3. 6 gives the results of the formant frequency measurements of the items in Part III. The first two examples in the table are the cases in which cada is used substantively and takes on stress; the other two are examples of cada's normal use. The /a/ in question does not take on stress in these cases. At least one thing is certain in the above data: the F1 values of the items that take on (sentence level) stress are definitely greater than those that do not take on stress. However, the stressed cases neither fall under the stressed /a/ in Part I, nor do the unstressed cases fall under the unstressed /a/ in Part I. Therefore the comparison

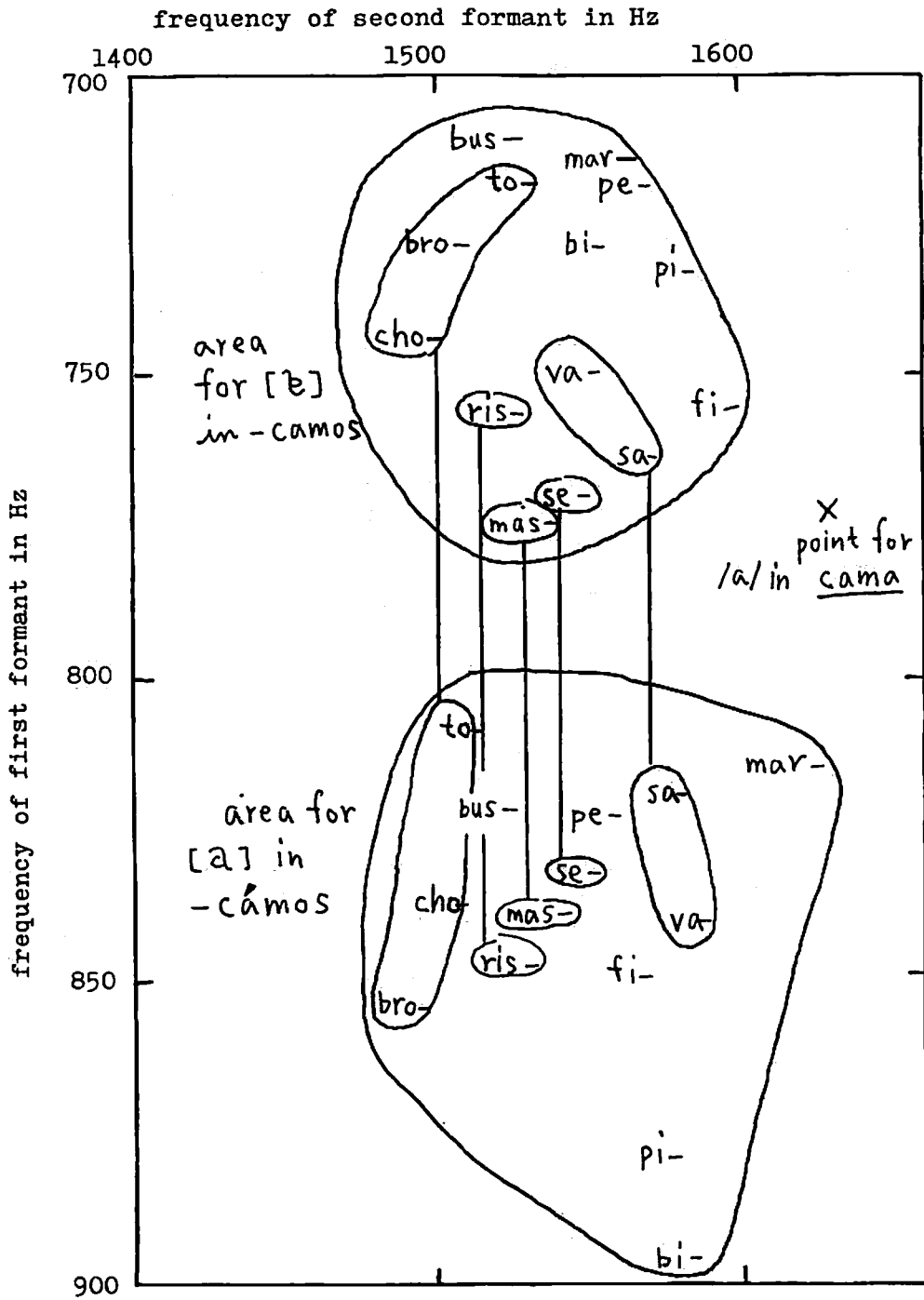


Fig. 3. 8. Idiosyncrasy of each item is apparent as to the F2 value.

with the previous data seems impossible. This may be due to the difference of the phonetic environment.

Table 3.6 Average formant frequencies of the items in Part III. Standard deviations are shown in parentheses.

	F1	F2	F3
"dois de <u>ca</u> da"	733(46)	1460(43)	2770(N=1)
"dois para <u>ca</u> da"	797(31)	1507(17)	2590(N=1)
"dois de <u>ca</u> da um"	627(34)	1513(19)	2747(49)
"dois para <u>ca</u> da um"	660(37)	1553(73)	2583(181)

3.5 Concluding remarks

What we have verified in the present experiment are as follows:

- (1) A stressed /a/ followed by a nasal consonant shows smaller F1 values than a stressed /a/ followed by a non-nasal consonant, and greater F1 values than the unstressed /a/. The effect of nasalization is present.
- (2) There is a distinct difference in the phonetic quality between the stressed vowels of the 1st person plural present forms of the 1st conjugation verbs and those of the preterit forms. The former verbs show normal pattern of the stressed /a/ when it is followed by a nasal consonant, while the latter ones show anomalous [a] in this environment, as has been traditionally stated in the literature. However, to pronounce the latter forms requires more effort than the former, as the increase in duration shows.

Also, the following questions have been raised:

- (1) Although the effect of nasalization exists, the magnitude of the effect is not sufficient to allow us to identify the stressed /a/ followed by a nasal consonant (i. e. [ɤ]) with unstressed /a/ (i. e. [ɛ]). This finding runs against the traditional observation, according to which both would have an identical phonetic quality, as is indicated by the phonetic transcriptions of these two sounds.
- (2) The process of producing [a] before /m/ is rather unclear; there are two possibilities:
 - (a) Our subject may have produced [a] before /m/ merely in response to the acute accent that appears in orthography, not knowing that he was producing [a].
 - (b) The subject may have intended to produce [a], and so he did.

Phonologically, the alternative (b) is more interesting. In that case it is implied that the speaker has the knowledge of the surface [ɛ] that appears usually in the position followed by a nasal consonant.

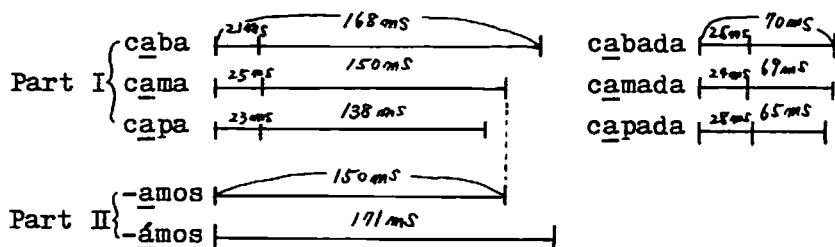
Notes

1. This study is concerned only with Lusitanian Portuguese, and Brazilian Portuguese will not be taken into account.
2. This feature system is adopted in Mateus (1973) and other studies.
3. This rule is proposed by both Mateus (1973) and Saciuk (1970), but details concerning the treatment of the rule differ according to each author.
4. This schwa may be derived from an underlying /e/, although this is not so simple a matter since in unstressed position there is no /e/-/ɛ/ distinction.
5. The notation [ɐ] prevails in the literature of Portuguese phonology. Barbosa (1965) avoids this, however, for reasons which are not clear.
6. In Mateus (1973), falamos and falámos have the following underlying representations:

falamos /fal+a+muS/
 falámos /fal+a+[-cons]+muS/

Thus the segment [-cons] in the latter blocks the application of the nasalization rule, since thematic /a/ is not immediately followed by /m/ in the underlying representation. But the motivation for having the segment [-cons] in this position is not so clear, in spite of her morphological arguments.

7. Usually in the so-called nasal vowel of the type /VNCV/, the /N/ realizes as a nasal consonant, being assimilated to the following consonant. But when the /C/ happens to be a continuant, the cluster /VN/ appears as a true nasal vowel.
8. The recording took place at the Research Institute of Logopedics and Phoniatics, Faculty of Medicine, University of Tokyo, on Nov. 7, 1979.
9. If we compare the durations of the vowels in Part I with those of the vowels in Part II, it can be concluded that the duration of /a/ in -amos goes together with those of the items in Part I and that the /a/ in -ámos is extra-long (but items in Part I consist of two syllables while items in Part II consist of three and therefore, strictly speaking, this comparison is not satisfactory). These relationships are summarized below:



(Each value of the item in Part I is an average of six utterances, and the duration of aspiration is given in parentheses. Durations of /a/ in -amos and /a/ in -ámos are averages over the total occurrences of these forms.)

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